

74
NEW ZEALAND

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

INFORMATION SERIES No. 74

Biological Control of Weeds in New Zealand 1927-48

by

DAVID MILLER

(Formerly Director of Cawthron Institute
and Entomology Division,
Department of Scientific and Industrial Research)

1970



11-

NEW ZEALAND
DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

INFORMATION SERIES No. 74

Biological Control of Weeds in New Zealand 1927-48

by

DAVID MILLER

(Formerly Director of Cawthron Institute
and Entomology Division,
Department of Scientific and Industrial Research)

1970

Price: \$2.50

N.Z. Dep. scient. ind. Res. Inf. Ser. 74

© Crown Copyright 1970

CONTENTS

	PAGE
INTRODUCTION	5
BLACKBERRY (<i>Rubus fruticosus</i> L.)	8
Introduction	8
Insects of Blackberry	8
New Zealand	8
Hawaiian Islands	9
North America	9
Great Britain and Europe	12
Other Countries	13
Ecology of Blackberry	14
Insects Selected	15
<i>Coraebus rubi</i> (L.)	15
Bionomics	15
Consignments	17
Experiments with Beetles	22
Infestation Tests	24
Other Insects	25
GORSE (<i>Ulex europaeus</i> L.)	27
Introduction	27
Phenology of Gorse	27
Insects of Gorse	29
<i>Apion ulicis</i> Forst.	30
Description	30
Bionomics	31
Britain and Europe	31
New Zealand	37
Methods of Shipping	40
Consignments	41
Studies in New Zealand	42
Methods	42
Consignments Collected August, September, October	44
Consignments Collected November, December, January	47
Consignments Collected February, March, April	51
Consignments Collected May, June, July	53
History of New Zealand Generations	53
Tests on Plants of Economic Importance	56
Liberation and Establishment	56

CONTENTS — *continued*.

	PAGE
PIRIPIRI <i>Acaena anserinifolia</i> (J. R. et G. Forst.) Druce	59
Introduction	59
Insects of Piripiri	59
New Zealand	59
Australia	60
Chile	60
<i>Antholcus varinervis</i> (Spin.)	60
Methods of Shipping	60
Rearing Methods	61
Consignments	62
Bionomics	63
Chile	63
New Zealand	65
Preference and Starvation Tests	67
Liberation and Establishment	67
RAGWORT (<i>Senecio jacobaea</i> L.)	73
Introduction	73
Ragwort Insects	73
New Zealand	73
Britain and Europe	74
<i>Tyria jacobaeae</i> L.	75
Bionomics	75
England	75
New Zealand	75
Consignments	76
Shipping and Rearing Methods	76
History of Consignments	78
Tests on Plants of Economic Importance	80
Liberation and Establishment	81
<i>Hylemyia seneciella</i> (Meade)	82
Description	82
Bionomics	84
Consignments	86
Techniques of Shipping and Rearing	86
Tests on Plants Other Than Ragwort	88
History of Consignments	88
Liberation and Establishment	97
ST. JOHN'S WORT (<i>Hypericum perforatum</i> L.)	99
Introduction	99
<i>Chrysomela hyperici</i> Forst.	99
Description	99
Bionomics	99
Liberation and Establishment	100
REFERENCES	102

GENERAL INTRODUCTION

In 1927 biological control of New Zealand weeds by means of insects was inaugurated by the Cawthron Institute, and the work was continued there until 1948. In 1936 the Department of Scientific and Industrial Research established a Division of Entomology at Palmerston North. To consolidate the entomological research of the country, that Division was transferred to Nelson in 1937 where it operated with the Department of Entomology of the Cawthron Institute until 1956 as the Entomological Research Station. In 1956 the entomological activities of the institute ceased and were taken over by the Division of Entomology of the Department of Scientific and Industrial Research.

As the biological control of weeds has again been undertaken by the Division of Entomology since 1956, the Department of Scientific and Industrial Research deputed the writer to prepare, from the records still available, a history of the work carried out by the Cawthron Institute between 1927 and 1948. Until now only occasional articles on special features have been published.

Successes in biological control of weeds in other countries (Hawaiian Islands, Fiji, and Australia) led the late Dr R. J. Tillyard, when Biologist at the Cawthron Institute, to initiate a similar project in New Zealand. In 1926, with the support of the late Sir G. A. K. Marshall, Dr A. D. Imms, and Dr L. O. Howard, he secured from the Empire Marketing Board an annual grant of £2,000 for a period of five years; this was subsidised by £1,000 per annum by the New Zealand Government, and a similar amount in services and facilities was given by the Cawthron Institute Trust Board.

To provide extra accommodation at the Cawthron Institute the Empire Marketing Board authorised an additional sum of £1,333, brought up to £2,000 by a New Zealand Government subsidy, for capital expenditure on additional laboratory and quarantine insectary buildings, and the Cawthron Trust Board gave land for the buildings and an experimental area together with the fittings and furnishings of the laboratories. Toward the close of 1927, the new buildings were completed, and the opening ceremony was performed on 13 December by the Rt. Hon. L. S. Amery, P.C., then Secretary of State for the Dominions. In the same year, Dr Tillyard accepted a post with the Commonwealth Government at Canberra and relinquished his position at the Cawthron Institute at the end of February 1928. The writer succeeded him two months later, the interim responsibility for the researches being in the hands of the late Mr A. L. Tonnoir, Field Entomologist in the weed-control scheme.

In addition to the work done in New Zealand, it was necessary to have assistance in the countries that were supplying the insects. Originally the work in Britain and Europe was organised by Dr A. D. Imms, of the Rothamsted Experimental Station, in co-operation with Professor J. W. Heslop-Harrison, of Armstrong College, Newcastle-on-Tyne, all the insect consignments having been sent through Dr Imms. After the first 18 months, however, the writer centralised the activities under Dr W. R. Thompson, Director of the newly founded Parasite Laboratory at Farnham Royal, England, that institution having been established by the Empire Marketing Board to supply the Empire with parasitic insects. In North America help was given free of charge by Dr L. O. Howard, then Chief of the Bureau of Entomology at Washington, D.C. In the meantime, surveys of insects likely to be of use in New Zealand were made in Britain, Europe, and North America, first by Dr R. J. Tillyard and later by the writer. In South America, Brother Claude Joseph (H. Janvier), of the Instituto San José at Temuco, Chile, undertook a study of the insects of piripiri (*Acaena*), and as a result the writer visited that country in 1930 and 1935 to organise the work and arrange methods of dealing with consignments; the Chilean activities were supported by funds provided by the New Zealand primary producers and by the Cawthron Trust Board.

At the end of the five years during which the work had been financed by the subsidised Empire Marketing Board's grant the total funds had not been spent, but authority was secured to continue the work until the full amount had been used; this sufficed for a further year at a critical period when the influence of the economic recession of the thirties was coming to be felt in New Zealand. The Empire Marketing Board's grant eventually expired on 31 March 1933, when there were indications of definite progress in some of the research. The Empire Marketing Board had ceased to function, so there was every likelihood of research being abandoned, large stocks of insects destroyed, a valuable staff disbanded, six years' labour lost, and some £15,600 spent to no purpose. The writer appealed to the primary producers of the Dominion, and the Meat Producers' Board, the Farmers' Union, the Dairy Board, and other organisations came to the rescue, thus allowing the work to be maintained until 1938, by which time the position had stabilised.

During the period when the insects were being imported from Britain, Europe, United States, and Chile there was no air transport, and one of the most critical aspects was the shipment of the material. In this we were fortunate in having the co-operation of shipping companies in the transportation of consignments in the vegetable chambers of their ships. For such aid, acknowledgments are due to the New Zealand and Shaw Savill and Albion Lines, plying between England, Panama, and the Dominion, the Grace Line, between Valparaiso and Panama, and the Union and Anchor Shipping Companies between New Zealand ports. Furthermore, the help of the British Consular Services in Chile and at Panama for supervising the despatch of consignments was greatly appreciated. The writer also records his personal indebtedness to the

late Mr A. L. Tonnoir who managed the research until 1929, to Messrs C. H. G. Fraser and J. M. Kelsey whose initiative did so much to maintain the work, to Mr E. S. Gourlay who was responsible for collecting and despatching for distribution the gorse-seed weevil and the St. John's wort beetle, and to Miss Rona Johnson who typed the final script of this memoir for publication.

The basic activities of the project to biologically control weeds in New Zealand were to secure suitable insects, ascertain their effectiveness, test them on economic plants (both in their country of origin and in the Dominion), and ultimately establish them in the field if they promised to be useful and had passed all safeguarding requirements. The insects were studied under strict quarantine conditions. Neither the staff nor the finance were available to adequately undertake fundamental research on many other interesting aspects that arose during the investigations; nevertheless, a considerable amount of useful data was incidentally gathered on the bionomics of the insects concerned.

The weeds dealt with were blackberry, gorse, ragwort, piripiri, and St. John's wort; information was gathered on insects infesting other weeds, but no research was carried out. The blackberry project was abandoned because of the risk of damage to related economic plants by the only insect studied (*Coraebus rubi* (L.)), but insects were liberated against the other four weeds. The establishment of the seed weevil (*Apion ulicis* Forst.) against gorse was universal, and it is now one of the commonest insects in the country; however, the weevil has proved inadequate even though it destroys a high percentage of seeds. Two insects, the cinnabar moth (*Tyria jacobaeae* L.) and the seedfly (*Hylemyia seneciella* (Meade)), liberated against ragwort, did establish but they have little influence, if any. The Chilean sawfly (*Antholcus varinervis* (Spin.)), against piripiri, apparently has been unable to maintain itself in the field. On the other hand, a spectacular success against St. John's wort was secured, particularly in one locality at least, by the chrysomelid beetle (*Chrysomela hyperici* Forst.).

Though biological control seemed to be the only practicable means of dealing with the weed problem several years ago, the scene has changed with the use of effective sprays, the development of better farm techniques, and closer settlement in some districts. It is obvious, however, that the weed problem has been, and still is, the result of plant competition on areas of reverted and abandoned land, as well as of poor farming in many places where the problem could readily be controlled by management. Nonetheless, biological control still appears to be the most hopeful means of attack against some weeds in some localities; but the successful biological control of any weed is futile unless something useful is grown in place of the weed.

BLACKBERRY

Rubus fruticosus L.

INTRODUCTION

In New Zealand, blackberry is common, and often abundant, in regions of higher rainfall, except where there is well established pasture or where the land is under cultivation. In regions of lesser rainfall there are many districts where a bush is seldom, if ever, seen.

According to Allan (1940) this European weed in New Zealand is a complex of several imperfectly known forms grouped under the collective name of *Rubus fruticosus*, so the question of hybridisation arises; Allan gives the following components of the complex.

Rubus laciniatus Willd., common in both islands, hybridisation between it and one or other of the *fruticosus* components being common; *R. pubescens* Wimmer, in the neighbourhood of Wellington; *R. thyrsoides* Wimmer, in a few localities of the North Island; *R. radula* Weihe, in a few localities of the Wellington Province; *R. rudis* Weihe et Nees, noted near Wellington City; *R. vestitus* Weihe et Nees, in several localities in both islands; *R. conspicuus* Müller, in several localities of both islands, apparently including the forms referred to *R. leucostachys* Sm. by Kirk (1899); *R. ulmifolius* Schott (*R. discolor* Weihe, *R. rusticanus* Mercier), common in both islands, but apparently more abundant in the North; *R. macrophyllus* Weihe et Nees, occasional in both islands, but apparently more common in Westland, the variety *schlechtendalii* Weihe appearing to be confined to the north of the South Island.

INSECTS OF BLACKBERRY

When considering insects for the biological control of blackberry, a fundamental difficulty arose in that the weed is so closely related to many rosaceous plants of economic importance; further, the selection of insects for study was complicated by the fact that a review of the species recorded from the weed in many parts of the world showed that few, if any, were solely restricted to blackberry. The following are the salient records gathered in New Zealand and overseas.

NEW ZEALAND

Several insects frequent blackberry in New Zealand, but any damage to the weed is temporary and localised and is attributable to only five species: *Eucolaspis brunneus* (F.), *Ctenopseustis obliquana* (Walk.) and *Mecyna flavidalis* Dbld., which attack the foliage; the larva of a

cerambycid, perhaps *Oemona hirta* (F.), which bores in the stems; and *Carposina adreptella* (Walk.), which breeds in shoots, buds, and fruits. The first four, and probably the fifth, are native species. Among other insects can be noted the exotic *Aulacaspis rosae* Bouché, *Eulecanium corni* Bouché, *Sepheha cinerea* Kirk, and *Scolypopa australis* Walk.; there are also a species of *Erythroneura* and of a collembolan (in fruit) both of which could be either native or exotic. Nothing is known about the last two, but all the others are polyphagous, *E. brunneus* and *C. obliquana* being pests of fruit and other trees, and *C. adreptella* of raspberry.

Apart from the foregoing insects, reference should be made to a mite (*Aceria essigi* Hassan) that is responsible for "red-berry" disease of blackberry in parts of the Dominion. It is thought to be of European origin, and was first reported in New Zealand by Hamilton (1949). It is also established in the United States of America where it attacks raspberry and loganberry. It was not intentionally introduced and could have been accidentally carried from England on apple stocks imported to Nelson, where it had made its first appearance in New Zealand shortly after the arrival of a consignment of stocks.

HAWAIIAN ISLANDS

A rare Hawaiian cerambycid (*Plagithmysus viticollis* Sharp) bores in the stems of native blackberry (*Rubus hawaiiensis* Gray).

NORTH AMERICA

Hymenoptera	<i>Diastrophus bassettii</i> Beut.	Root and crown gall
	<i>D. cuscuteaeformis</i> O-S	Seed gall
	<i>D. kinkaidii</i> Gill.	Stem gall
	<i>D. nebulosus</i> (O-S.)	Stem gall
	<i>D. radicum</i> Bass.	Root gall
	<i>Diplolepis rubicola</i> (Kieff.)	Stem gall
	<i>Hartigia cressonii</i> (Kirby)	Stem borer
	<i>H. trimaculata</i> (Say)	Stem borer
	<i>Metallus rhoweri</i> MacG.	Leaf miner
	<i>Monophadnoides feniculatus</i> (Harr.)	Defoliator
	<i>Pamphilus dentatus</i> MacG.	Defoliator
Coleoptera	<i>Agrilus ruficollis</i> (F.)	Stem gall
	<i>Byturus unicolor</i> Say	Foliage and buds
	<i>Oberea bimaculata</i> Oliv.	Stem gall and girdler
Lepidoptera	<i>Bembecia marginata</i> Harris	Root borer
	<i>Nepticula rubifoliella</i> Clem.	Leaf miner
	<i>N. villosella</i> Clem.	Leaf miner
	<i>Schreckensteiniella festaliella</i> Hb.	Defoliator
Diptera	<i>Camptoneuromyia rubifolia</i> Felt	Leaf-margin gall
	<i>Cecidomyia mucosa</i> Steb.	Leaf-vein gall
	<i>Lasioptera farinosa</i> Beut.	Leaf gall
	<i>Phorbia rubivora</i> Coqu.	Stem borer

HYMENOPTERA

Diastrophus bassetti ranges through the eastern United States, and constructs a polythalamous gall on the canes of the trailing blackberry (*Rubus canadensis* L.) close to, or partly below, the ground surface; the gall is fleshy and almost globular.

Diastrophus cuscutaeformis occurs in Canada and the United States, and forms monothalamous galls on the stems of blackberry (*Rubus villosus* Ait., *R. canadensis* L. and *R. cuneifolius* Pursh) in the form of numerous small, globular, woody, seed-like structures closely packed together and clothed with spines or filaments.

Diastrophus kinkaidi is found in California, Washington and Idaho. The larvae construct polythalamous galls on the canes of blackberry (*Rubus nutkanus* Moc. ex Seringe); the galls are abrupt swellings surrounding the canes, and measures about $2\frac{1}{2}$ in. long by $1\frac{1}{2}$ in. diameter.

Diastrophus nebulosus is the gout or pithy gallfly widely distributed in Canada and the United States. Although it is not a serious pest, the polythalamous galls form irregular masses on the stems of blackberry (*Rubus villosus* Ait.) and red raspberry (*R. strigosus* Mich.).

Diastrophus radicum occurs in Canada and extends into North Carolina, Michigan and Colorado; it forms polythalamous galls on the roots of the running blackberry, or dewberry (*Rubus canadensis* L.), black raspberry (*R. occidentalis* L.) and the high-bush blackberry (*R. villosus* Ait.). Sometimes the entire root stock above and below ground is surrounded by an almost solid mass of galls.

Diplolepis rubicola causes a small unilateral or two-chambered gall on canes of blackberry.

Hartigia cressonii. In Canada, Nevada, and California the larvae of this sawfly burrow in the succulent tips of young shoots of blackberry, raspberry, loganberry, and rose, and thence down through the pith to the base of the canes.

Hartigia trimaculata is a sawfly that attacks roses and raspberries in the eastern United States, causing considerable damage to buds when the female punctures the tissues during oviposition; the larvae bore downwards in the twigs and canes, which wilt as a result.

Metallus howeri, the blackberry leaf miner. This tenthredinid has inflicted serious injury to the foliage of raspberry, blackberry, and dewberry in the United States and Canada. The larvae form blotch mines in the leaves and destroy all but the epidermis.

Monophadnoides feniculatus is a tenthredinid that ranges throughout northern United States and southern Canada, where it seriously injures blackberry, raspberry, and dewberry. The larvae make oblong or irregular holes in the foliage, or may completely strip the leaves to the midrib; at times bark, young growth, buds, and fruit are attacked. The leaves are also injured by the deposition of the eggs just beneath the cuticle.

Pamphilius dentatus. The larva of this sawfly is a defoliator; it confines its attention to, and seriously damages, blackberry, not attacking red or black raspberries even when these are adjacent to infested plants. Its habits are similar to those of the peach sawfly (*P. persicum* MacG.).

COLEOPTERA

Agrilus ruficollis, the red-necked cane-borer, is a buprestid widely distributed from Canada over the eastern United States to the Gulf of Mexico. The larvae burrow in the canes of blackberry, dewberry, and raspberry, causing spindle-shaped galls 1 to 3 in. long; the canes are weakened and fruiting is prevented. At Arlington (Washington, D.C.) the writer observed that 75% of blackberry canes in one plantation had been killed by this insect.

Byturus unicolor. This byturid beetle often seriously injures the raspberry crop in eastern Canada and the United States by feeding on the buds, tender leaves, and blossoms. It eats its way into a cluster of blossom buds and punctures them; it also skeletonises the leaves and devours the stamens and pistils of flowers; young larvae burrow into the fruit receptacle.

Oberea bimaculata. The larvae of this cerambycid beetle bore into the canes of wild raspberries in Canada and northern United States; cultivated raspberries and blackberries are also attacked, and the insect has been occasionally recorded from the shoots of apple and witch hazel. Infested *Rubus* canes die before the fruit ripens, as the larvae burrow downward in a sinuous course, often to the base, where they frequently enter the woody parts. When ovipositing, the beetle girdles the cane, which wilts and droops above the injury.

LEPIDOPTERA

Bembecia marginata, the blackberry crown borer. An aegerid moth that ranges between the Atlantic and Pacific coasts of North America in the region of Canada and the northern United States. The larvae bore into the crown of plants, causing extensive damage to blackberry and raspberry.

Nepticula rubifoliella and *N. villosella*. The larvae of both these moths are leaf miners of blackberry.

Schreckensteinia festaliella is a tineoid moth that occurs in Europe and North America; in the latter country it is a very rare pest of blackberry, but it can cause great damage as a defoliator.

DIPTERA

Camptoneuromyia rubifolia. The larvae of this midge cause a leaf-margin gall on blackberry.

Cecidomyia mucosa. This midge is responsible for the "mossy leaf gall" of blackberry (*Rubus nigrobaccus* L. H. Bailey). The gall is very

small, polythalamous, and occurs at the union of leaflets or on the mid vein.

Lasioptera farinosa is an imperfectly known leaf-gall midge of blackberry about which no details are known.

Phorbia rubivora, the raspberry-cane maggot fly, occurs over the northern United States and in Canada; its larvae bore in the canes of red and black raspberry and blackberry.

GREAT BRITAIN AND EUROPE

Hymenoptera	<i>Diastrophus rubi</i> Htg.	Stem gall
Coleoptera	<i>Byturus tomentosus</i> (F.) <i>Coraebus rubi</i> (L.)	Foliage and buds Stem and crown borer
Lepidoptera	<i>Bembecia hylaeiformis</i> Lasp. <i>Cidaria albicillata</i> (L.) <i>Habrosyne derasa</i> (L.) <i>Nepticula aurella</i> Staint. <i>N. rubivora</i> Wocke <i>Notocelia uddmanniana</i> (L.) <i>Thyatira batis</i> (L.) <i>Tischeria marginea</i> Hw. <i>Schreckensteiniella festaliella</i> Hb.	Stem and root gall Defoliator Defoliator Leaf miner Leaf miner Leaf roller Defoliator Leaf miner Defoliator
Diptera	<i>Contarinia rubicola</i> Rub. <i>Lasioptera rubi</i> Heeg. <i>Perisia plicatrix</i> (H. Loew)	Attacks flower buds Stem gall Deforms leaves
Hemiptera	<i>Typhlocyba tenerrima</i> H-S	Attacks foliage

HYMENOPTERA

Diastrophus rubi. The larvae produce galls from 2 to 8 in. long on the canes of blackberry, dewberry, and European raspberry.

COLEOPTERA

Coraebus rubi. This buprestid beetle ranges through Spain and central Europe into Asia Minor. The larvae tunnel in the stems of only *Rubus fruticosus* and roses, especially the long water shoots of Frau Karl Druschki; there is one brood annually. As much as 60% of infested blackberry has been known to have been seriously damaged, and though not known to attack raspberry the insect has caused alarm by its depredations upon the extensive areas of roses cultivated for perfume.

Byturus tomentosus. This beetle attacks the foliage and buds of wild blackberry, and the larvae breed in the fruit. However, it is a serious pest of cultivated raspberry.

LEPIDOPTERA

Bembecia hylaeiformis ranges through central Europe and is most common in Austria and Hungary. The larvae attack blackberry, raspberry, and dewberry by boring into the roots and forming galls on the crown.

Cidaria albicillata, the beautiful carpet moth. The larvae feed on the foliage of blackberry, raspberry, and wild strawberry.

Habrosyne derasa, the buff-arches moth. The larvae normally attack blackberry foliage and very rarely touch raspberry.

Nepticula aurella mines in the leaves of blackberry, strawberry, agri-mony, and rosewort.

Nepticula rubivora mines in the leaves of blackberry and dewberry.

Notocelia udmanniana. The larvae of this common insect are leaf rollers attacking blackberry and raspberry.

Thyatira batis. A common moth the larvae of which attack the foliage of blackberry and raspberry.

Tischeria marginea. The larvae of this common tineoid moth construct mines and blotches in blackberry leaves; there is no other known host.

Schreckensteinia festaliella occurs also in North America and is referred to under that heading.

DIPTERA

Contarinia rubicola. The larvae attack the flower buds, which remain unopened; the hosts are wild and cultivated species of *Rubus*, including blackberry and dewberry.

Lasioptera rubi forms galls on the stems of blackberry, loganberry, raspberry, and dewberry.

Perrisia plicatrix malforms the leaves of blackberry, raspberry, and dewberry. In association with the orange rust fungus (*Phragmidium violaceum*) it causes great damage to blackberry in Spain.

HEMIPTERA

Typhlocyba tenerrima. This small leaf hopper is very rare in England and Europe, but it is probably capable of causing much damage; as far as is known it attacks only blackberry.

OTHER COUNTRIES

Practically no data have been gathered from countries other than those dealt with above. Inquiries in South Africa revealed that blackberry is a problem there as it is in New Zealand, and that the larvae of the blackberry fly, *Ceratitis rubivora* Coq., are solely confined to the fruit of blackberry. In India the Chief Entomologist at the Pusa In-

stitute reported in 1927 that various species of wild *Rubus* were very common in practically all the hill tracts of India, especially along the Himalayas, 41 distinct species having been described in the "Flora of British India". *Rubus fruticosus* occurred on the western temperate Himalayas from Marrai to Jammu, at altitudes of from 3,000 to 7,000 feet, while raspberry (*R. idaeus* L.) was very little cultivated. Though many insects occurred on the various species of wild *Rubus*, practically nothing was known of their life histories and of their particular food preferences.

ECOLOGY OF BLACKBERRY

Though only insects were considered as agents in the biological control of blackberry, the following observations by Professor Heslop-Harrison, of Durham University, on the ecology of the weed are noteworthy (Harrison, correspondence, 1928).

In Britain and Europe blackberry and its enemies were studied under natural conditions in the weed's various types of habitat. The vegetative spread of blackberry is very rapid. An isolated thicket at Birtley, Durham, never fruited and was left untouched in order to observe its spread. In one season it had made a frontal advance of over 1½ metres, so factors restraining vegetative growth are at least as important as the control of seeding.

(a) *Moorland and similar habitats on higher ground.* Here the plant stabilises itself naturally, although where it comes into contact with *Pinus sylvestris*, or, in fact, any conifer, its growth is inhibited.

(b) *Wooded coastal denes, and low country away from coast.* Here again natural competition checks the weed; in addition vegetative progression is limited by the gall gnat, *Perrisia plicatrix*, and in many of the woods enormous numbers of the berries are partly, or wholly, destroyed by the larvae of the beetle *Byturus tomentosus*. Aiding these checks are the two fungi *Phragmidium violaceum* and *P. rubi*. On one of the lowland fells many plants were quite destroyed, and others weakened, by the fungus *Coniothyrium fuckelii*, which also attacks cultivated forms of *Rubus*, killing some and preventing fruiting in others.

(c) *The Pyrenean gorges.* Great damage was done to blackberry by a combination of the fungi *Phragmidium violaceum* and *P. rubi* in conjunction with the cecidomyids *Perrisia plicatrix* and *Lasioptera rubi* and the cynipid gall *Diastrophus rubi*, whole bushes being destroyed.

In all the areas investigated the moths *Thyatira batis*, *Habrosyne derasa*, and *Nepticula aurella*, the coccid *Aulacaspis rosae*, the cecidomyid *Contarinia rubicola*, and various eriophyid mites were more or less destructive.

In connection with Harrison's observations it is to be noted that in New Zealand the conidial stage (*Coniothyrium fuckelii*) of the raspberry cane wilt (*Leptosphaeria coniothyrium*) is destructive at times;

Cunningham (1922, 1927) concluded from investigations that the fungus "causes little or no real damage to blackberry plants, though, where infection is severe, fruiting on certain varieties may be entirely prevented" (1922).

INSECTS SELECTED

It is clear that only two of the species in the foregoing lists are confined solely to blackberry—*Ceratitis rubivora* (South Africa) and *Typhlocyba tenerrima* (Britain and Europe). The information about them, however, was quite inadequate.

In 1926 Tillyard selected eight species: from Britain and Europe, *Cidaria albicillata*, *Coraebus rubi*, *Lasioptera rubi*, *Perrisia plicatrix*, and *Thyatira batis*; from United States of America, *Agrilus ruficollis*, *Bembecia marginata*, and *Diastrophus nebulosus*. Consignments of these insects were shipped to New Zealand during 1926 and 1927, but when the writer took over the research in 1928, the importation of, and work on, all but *Coraebus rubi* was discontinued. In the early stages of the work, some limited study was carried out with *Agrilus ruficollis*, *Bembecia marginata*, and *Thyatira batis*, but nothing was attempted with the remaining species and the consignments were destroyed.

Coraebus rubi was selected as the most suitable insect because it was reported to severely damage blackberry and was not known to attack raspberry, and because its only recorded host other than blackberry was the China rose (*Rosa indica*) used in Europe as the stock for the propagation of the Frau Karl Druschki and other varieties.

Since the insect damages *Rosa indica*, a questionnaire on the use of that rose was circulated among a number of leading nurserymen in New Zealand. The replies agreed that *R. indica* was not grown to any extent in this country and that the principal stocks in use were about four varieties of *Rosa canina* (dog rose); two varieties (Dickson's and Dawson's) of *Rosa simplex* (multiflora and polyantha) in the North Island; a single pink rose, *Rosa manetti*, widely used together with Lippiatt's Manetti, the former as stock for Frau Karl Druschki; and *Rosa laxa*, which is infrequently used.

CORAEBUS RUBI (L.)

BIONOMICS

The buprestid beetle *Coraebus rubi* is 8 to 10 mm long (Fig. 1); the narrow body, which is attenuated posteriorly, is blackish bronze, the elytra being ornamented with undulating fasciae of greyish hairs. The short head is concealed up to the eyes by the prothorax, and the pectinate antennae are 11-jointed. The whitish, narrow-bodied larva measures up to 20 mm long by 3 mm wide when mature.

In Europe, according to Génieys (1927), the first *Coraebus* beetles appear about the end of May, or early June, being subject to variations

in temperature; they frequent spots exposed to the sun, and eat from the edges of foliage. Sudden and heavy rains cause the beetles to drop to the ground where they lie motionless embedded in mud, and there many perish.

The males live from four to five, and the females from seven to eight weeks. Oviposition commences from 15 to 18 days after beetle emergence, the eggs being placed on the bark of medium-sized canes near the ground, and covered with a viscous protecting fluid that sets rigidly; from 40 to 50 eggs are laid by a female at the rate of one or two a day. When the larvae hatch in 18 to 20 days, they enter the bark within an hour, and during the next 60 days tunnel downwards in a spiral close under the bark (Fig. 2). At the end of that time the third moult occurs, and the larvae tunnel deeper and continue downwards, the spiral becoming closer; the descent takes six months to complete.

About the end of December, or in early January, after a possible fourth moult, the larvae begin to ascend through the pith in a more or less direct course, each to finally pupate in a chamber it constructs at a point close to the bark near where it had entered as a young larva; the larval ascent takes from two and a half to three and a half months to complete. According to the severity of the winter, the larvae may have a hibernating diapause; pupation takes place during April and May, and the period is brief, varying according to temperature.

The greatest damage to the plant occurs where the larvae commence to ascend, which is usually about 10 in. below the point of larval entry, and where the close proximity of the spiral whorls cuts off the supply of sap. Usually there is only one larva in each cane. In vigorous plants with abundant foliage the sap apparently suffocates the larvae, while withered or weak plants do not afford sufficient nourishment for their growth.

The foregoing records by Génieys are here supplemented by observations made during the research in New Zealand.

(1) The larvae and pupae of *Coraebus rubi* readily respond to variations in temperature, and the life cycle can be so accelerated or retarded. Hibernation is apparently not obligatory.

(2) The pupal stage in one case was found to have lasted about two months at least.

(3) The beetles could live for as long as two months. Mating took place from time of emergence up to 14 days thereafter, the female being particularly active in this respect after feeding on blackberry foliage. Oviposition commenced two days later and continued for 28 days. Usually one egg was placed on a single cane, but sometimes two and three were found; sometimes oviposition occurred on leaves; as many as 28 eggs were laid by a female. Sometimes the downward burrow of the larva zig-zagged before following a straight course to the base of the cane.

(4) Even when the cane and crown were severely damaged the plant continued to throw out vigorous shoots.

(5) Though the larvae confined their attention to blackberry, the beetles fed freely on the foliage of different fruit trees, but not of strawberry.

(6) As well as *Coraebus rubi*, insects reared from imported material were 54 parasitic Hymenoptera, 51 tenthrinids, one crabronid, 35 lacewings, 21 moths, and one asilid; these numbers refer to individuals and not to species. There is now no record of the identity of these insects, but it is possible that the parasitic Hymenoptera could have been species recorded from *C. rubi* in Europe, and the others had doubtless used the burrows of that beetle for pupation or for shelter.

CONSIGNMENTS

Twenty-three consignments of *Rosa indica* rose stocks assumed to be infested with the larvae and pupae of *Coraebus rubi*, and one (5th) experimental shipment of eggs laid on blackberry canes were received at the Cawthron Institute from the south of France between 1927 and 1931 (inclusive); the stocks were packed in wooden containers without soil and transported in the vegetable chambers of ships at approximately 40° F.

The 5th consignment, comprising 580 eggs laid during the European summer of 1929, arrived during the New Zealand spring (September) of that year. Some of the eggs and canes were mouldy, and a dissection of 50 such eggs showed that 48% were apparently healthy and 2% dry. Of the remainder, some were placed in the heated glasshouse, and some in the large insectary subject to the atmospheric conditions of spring. The eggs in both locations were examined from time to time but nothing developed from them.

In Table 1 the months of dispatch and receipt of the consignments are set out with the number of rose stocks in each and the number of beetles secured.

The rose stocks had been collected in France each month from December to June during the years 1927 to 1931 (inclusive), so that any *Coraebus* present would have been in the different larval, or in the pupal, stages. Few of the consignments were studied individually, most having been dealt with in groups of two to five, so for the latter there are no data to indicate which consignments had produced beetles; consequently no comprehensive analysis can be undertaken to indicate the behaviour of the insect according to the stage in which it was transported. The one obvious feature is that the insect successfully survived the journey to New Zealand. The stocks were planted as required, with their crowns set in damp sand in insectaries.

In the following account 23 consignments are dealt with, the experimental consignment of eggs having been already referred to.

First consignment. This contained 37 well grown rose stocks assumed to have been infested; it was received in Nelson towards the end of March 1927. The stocks had been collected during January, or early

TABLE 1. *Coraebus rubi*.

Consignment	Month		Number of Stocks	Beetles Secured
	Dispatched	Received		
1	Feb 1927	Mar 1927	37	0
2	Mar 1928	Apr 1928	255	63
3	Mar 1929	Apr 1929	200	79
4	Mar 1929	May 1929	150	
5 (eggs)	Jul 1929	Sep 1929		
6	Feb 1930	Mar 1930	292	150
7	Feb 1930	Mar 1930	165	
8	Feb 1930	Apr 1930	470	100
9	Mar 1930	May 1930	860	216
10	Apr 1930	May 1930	360	82
11	Dec 1930	Jan 1931	130	6
12	Dec 1930	Jan 1931	71	
13	Jan 1931	Mar 1931	126	
14	Feb 1931	Mar 1931	268	225
15	Feb 1931	Mar 1931	270	
16	Feb 1931	Apr 1931	361	
17	Feb 1931	Apr 1931	362	43
18	Mar 1931	Apr 1931	307	
19	Mar 1931	May 1931	308	
20	Apr 1931	May 1931	331	293
21	Apr 1931	Jun 1931	1,346	
22	May 1931	Jun 1931	699	
23	May 1931	Jun 1931	729	
24	Jun 1931	Jul 1931	642	
		Totals	8,739	1,257

February at the latest, at a time when the insect was normally hibernating in an advanced larval state, and on arrival in New Zealand it would have pupated, or have been about to do so.

Up to the beginning of winter (May) the only emergent was a crabronid wasp, which seemed to have been sheltering in an old *Coraebus* burrow when the stock had been collected, as there was no evidence of the wasp having developed from stored paralysed insects.

As no *Coraebus* had emerged by November, individual stocks were opened from time to time; in only two was the insect present, in each stock a single dead beetle lying close to an exit hole of a characteristic burrow.

Second consignment. This consisted of 255 stocks: it was received at the end of April 1928, having been collected in France during February when the larvae were at the close of hibernation. Five stocks were opened in April; two of these each contained one healthy larva not far from pupation, and the remainder, though they contained no insects, had been infested before collection.

As winter was at hand (end of April), it was decided to ascertain, if possible, the influence of out-of-season low temperatures (the insects had already hibernated in France). So the consignment was held in cool

store (43° F) during May when the New Zealand winter had definitely set in, and then divided into three lots, each being removed from cool store and planted at different times during winter. However, it was found that all had been submitted to virtually the same temperature throughout. As no emergence of beetles had taken place by the end of November, two stocks were opened, and one of them contained two healthy pupae from which beetles emerged on 21 January 1929. Many of the stocks were growing well in November; as the shoots of some had died it was assumed that *Coraebus* was active within them, and no more were opened for examination. In January and February 1929, 63 beetles (two of which were dead) were secured from 55 stocks; of these beetles, 55 emerged between 7 and 24 January at almost daily intervals, after which emergences fell off markedly, being sporadic throughout February.

The above results are of interest in that the stocks had been infested by *Coraebus* during the European summer of 1927, that the larvae had hibernated naturally but had not matured to beetles until January and February 1929, after again passing through winter conditions in New Zealand; thus, the period under low temperature in New Zealand had seemingly retarded development.

Third and fourth consignments. The 3rd consignment of 200 stocks, collected during February, reached Nelson on 9 April 1929, and the 4th of 150 stocks, collected early in March, arrived on 1 May; in both cases the insect would have been in the late larval stage at the close of hibernation. The two consignments were dealt with together, and were divided into four lots; the first lot contained all of the 3rd consignment and the other three lots the 4th consignment; there are no data now available on the number of stocks in each lot, except that there were 64 in the first. The lots were planted at different times; the first three in the heated glass house under an average temperature of 70° F. and the fourth in an insectary where the atmospheric temperature averaged 56° F. Details are given in Table 2.

TABLE 2. *Coraebus rubi* (Consignments 3, 4).

Lot	Period in Cool Store	Planting of Stocks		Beetle Emergences		
		Month	Location	First	Last	No.
1	6 weeks at 40 deg. F	Apr	Glasshouse at 70 deg. F	Jul	Aug	12
2	*4 months at 43 deg. F	Jul	Glasshouse at 70 deg. F	Aug	Sep	8
3	*5 months at 43 deg. F	Aug	Glasshouse at 70 deg. F	Oct	Oct	10
4	*6 months at 43 deg. F	Sep	Insectary at 56 deg. F	Dec	Feb	49

* Includes 6 weeks of the period at 40 deg. F during transit.

These results indicate that the longer the period under low temperature the greater the retardation of the insect's development, even when that period is followed by high temperature, as shown by the history of the first three lots; retardation was most marked in the fourth lot,

which had been submitted to lower temperatures after removal from cool store, recalling the results with the 2nd consignment. The fact that the greatest number of beetles was secured from the fourth lot does not indicate any influence of prolonged low temperature; there was simply a greater number of *infested* stocks in that lot.

With the first and fourth lots two months had intervened between planting out and beetle emergence, even though the first lot had been under forcing conditions in the heated glasshouse and the fourth lot under much lower temperatures subject to daily fluctuations; with the third lot, one month intervened between planting and beetle emergence, and from the second lot the beetles appeared in the following month.

Sixth to tenth consignments. During 1930 these five consignments were received from France; they contained a total of 2,147 rose stocks. The 6th (292 stocks) and the 7th (165 stocks) consignments were collected in January during the time of larval hibernation and were received on 22 and 26 March respectively, when they were planted in the heated glasshouse (70° F.); their hibernation had been prolonged by seven and eight weeks accordingly. The 8th, 9th, and 10th consignments were collected during February when the larvae had emerged from hibernation, to be again submitted to low temperatures during transit, as well as for longer periods after arrival in certain instances. The 8th (470 stocks) was received in April, held in cool store for five weeks, and planted in an insectary during May at the onset of winter, having been subjected to 11 weeks of artificially low temperatures after leaving France at the end of February. The 9th (860 stocks) arrived in May, the journey having taken seven weeks; it was held in cool store for a further 13 weeks, and so had remained under low temperatures for 20 weeks. The 10th (360 stocks) also reached Nelson in May, when it was planted out in two lots after six weeks in cool store aboard ship; one lot of 240 stocks was placed in the heated glasshouse, and the other of 120 stocks in an insectary subject to temperatures of early winter. Table 3 shows the results of these experiments. They indicate that the development of *Coraebus* can be controlled by periods of varying temperatures, a matter of importance in the synchronisation of the insect with Southern Hemisphere seasons.

Eleventh to Twenty-fourth Consignments. For the 1931 work 5,950 rose stocks in 14 consignments were imported from France, and from them 567 beetles were secured. The history of these consignments is given in Table 4.

The 11th to 15th consignments were collected during the insects' period of hibernation (November, December, and January), the 16th to 22nd in the spring (February, March, and April) when the larvae were ascending in the plants, and the 23rd and 24th in the early summer (May) as the larvae were maturing, and perhaps pupating. All had been transported for six weeks at approximately 40° F in the vegetable chambers of ships. Consignments 11 to 13 were submitted to no further low temperatures and were planted out on arrival in the glasshouse

TABLE 3. *Coraebus rubi* (Consignments 6 to 10).

Consign- ment	Period in Cool Store (Weeks)	Planting of Stocks		Beetle Emergence		
		Month	Location	First	Last	No.
6	7	Mar	Glasshouse	May	Sep	150
7	8	Mar	Glasshouse	May	Sep	
8	11	May	Insectary	Dec	Feb	100
9	20	Aug	Insectary	Dec	Mar	216
10						
Lot 1	6	May	Glasshouse	Jul	Oct	72
Lot 2	6	May	Insectary	Dec	Dec	10

TABLE 4. *Coraebus rubi* (Consignments 11 to 24).

Consign- ment	Period in Cool Store (Weeks)	Planting of Stocks		Beetle Emergences		
		Month	Location	First	Last	No.
11	6	Jan	} Glasshouse	May	Jul	6
12	6	Feb				
13	6	Mar				
14	11	Apr	} Insectary	Nov	(1932) Jan	225
15	12	May				
16	11	May				
17	13	Jun	} Insectary	Nov	Jan	43
18	14	Jun				
19	12	Jun				
20	12	Jun	} Insectary	Dec	Feb	293
21	10	Aug				
22	10	Aug				
23	10	Aug				
24	9	Aug				

during January, February, and March. The glasshouse was not artificially heated, but the temperatures were higher than out of doors and fluctuated accordingly, yet beetle emergence took place at the normal European time in May until July. The development of the insects in the remaining consignments, irrespective of whether they had been collected during (14th and 15th), or after hibernation (16th to 24th), or even at the time of pupation (23rd and 24th), had been retarded by out-of-season periods in cool store before being exposed to seasonal temperatures in New Zealand from late autumn until the following summer. Variations in the numbers of beetles that emerged from the different groups of consignments mean little as the records of the number of infested stocks are now missing.

EXPERIMENTS WITH BEETLES

The beetles were collected twice daily as they emerged, and placed in mating cages. The cages measured $18 \times 21 \times 13$ inches; the long sides and top were made of glass, the ends of fine-meshed gauze, and the bottom of wood (see "Technique" under Gorse); blackberry twigs with leaves were supplied as food.

Segregation of the sexes was difficult as these could be distinguished only by the behaviour of the insects during pairing. The male was marked on the pronotum with red and the female with yellow after pairing had taken place. This method was satisfactory when only a few beetles had to be dealt with but was impracticable with large numbers; then a mating pair was put into a small gauze cage surrounding a blackberry cane, each pair being numbered in rotation when copulation was first observed, and both insects were removed to another cage after an egg had been deposited. The egg-bearing canes were numbered and labelled with all data for future reference. The small cages used for oviposition were of the "drum" type (see "Technique" under Gorse) fastened round the base of blackberry canes; they were kept under close observation, and blackberry leaves and water were supplied. When there was an excess of males, one was added to each female in the oviposition cages. The eggs were laid on the canes and on the twigs and leaves supplied as food for the beetles.

The males were most insistent in their courtship, whereas the females refused the males as long as they had not fed profusely; nevertheless, newly emerged females occasionally mated if subjected to electric-light radiation. Normally, pairing took place at the warmest time of the day (mostly between 1 and 2 p.m.) when cages were exposed directly to the sun. As sunny days did not prevail at the time of beetle emergence from many of the consignments, an electric bulb was fitted to the top of the mating cage to obtain the requisite light and temperature for pairing.

Though the longest lived beetle was a female kept under observation for four weeks before death, the life span under confined insectary conditions was much shorter than observed in the field by Génieys (1927). Usually the beetles died on the day of emergence, or one or two days thereafter.

Beetles of Second Consignment. Of the 63 beetles (35 males and 28 females) studied during January until March 1929, nine females laid 33 eggs; as many as 13 eggs were laid by a single female but the number was usually from one to four. Usually a single egg was laid on a cane, but sometimes there were two or three. Each cane with eggs bore a label on which was the code number of the ovipositing female as well as the date of oviposition. Eggs laid on foliage collapsed after two weeks.

The poor oviposition response was due to the lower temperatures prevailing, as no heated glasshouses were available at the time. Experiments showed that when some females were exposed to radiation from an electric light, better results were secured. By the end of March all

eggs were empty; either the larvae had hatched, or the eggs had collapsed before complete embryonal development. It was not possible to detect the entrance holes of larvulae into the canes after the spent eggs had been removed. During April and until June, 40% of the canes under observation had died back; all were opened in December, but in none was there any sign of infestation.

Beetles of the Third and Fourth Consignments. The stocks of these consignments were treated in four lots from which 79 beetles were obtained. From lot one 12 beetles developed, but all died without pairing or ovipositing, so the sexes could not be determined. Of the 18 beetles from the second and third lots, the six females produced 13 eggs in a week to a fortnight after emergence. The 49 beetles developing from the fourth lot comprised 35 males and 14 females, and seven of the latter laid 81 eggs; mating was observed from the first to the thirteenth day after emergence, and oviposition from two to 17 days later. The number of eggs laid by a female varied from one to 19, as many as seven eggs being laid by one female on the same day. The maximum period over which oviposition occurred was 15 days, and that was in January, the warmest month of the year.

Each blackberry plant, on the canes of which eggs had been laid, had been enclosed in a large gauze cylinder in order to check on any emerging beetles. One cane, on which an egg had been laid on 7 January, was opened for examination at the end of March; in it was a large larva that had burrowed downward in the normal manner. No more canes were opened until December, but no further infestation was found.

Beetles of the Sixth to Tenth Consignments. Of the 548 beetles obtained from these consignments, 93 were females. Though glasshouse conditions were favourable for the emergence and mating of beetles, the blackberry did not thrive there as well as it did out of doors. Under insectary conditions (equivalent to out of doors) mating did not occur as freely as in the heated glasshouse, but good results were obtained when the mating cages were placed in direct sunlight.

Most of the beetles laid from one to 10 eggs, though two laid 18 and 28, respectively, over periods of 26 to 28 days in January. During colder periods under heated glasshouse conditions, females oviposited almost as satisfactorily as they did in the insectary during summer, some females producing 13 eggs over periods lasting up to 16 days. Eggs were laid just as freely on raspberry as on blackberry.

All egg-infested blackberry and raspberry canes were finally opened for examination after sufficient time had elapsed for any beetles to have emerged. For raspberry the results were negative, but larval damage had been done to blackberry, sometimes to a marked degree, though there had been no beetle emergences. In some canes the downward burrow was not a complete spiral but zig-zagged at first before following a straight course to the base of the plant. Even from extensively damaged blackberry canes, vigorous shoots developed at points on the damaged parts.

Beetles of the Eleventh to Twenty-fourth Consignments. These consignments produced 567 beetles. The six beetles obtained from the 11th, 12th, and 13th consignments emerged during the New Zealand winter between May and July 1931 in the heated glasshouse; they had appeared at odd times and singly over the period, so no pairs were available at any one time before the insects died.

The 14th to 24th consignments (received from March to July 1931) contained a large supply of rose stocks. As it was known that *Coraebus* would attack blackberry and that quarantine conditions used with former consignments militated against the activity of the beetles, it was decided to provide the insects with conditions as near natural as possible, since summer was at hand when they emerged. For that purpose a large two-roomed insectary (enclosed with galvanised wire gauze which admitted a maximum of light under the circumstances) was erected and planted in readiness with blackberry; not only did the blackberry thrive (having to be pruned back from the walls) but so did the beetles, which lived for as long as two months, feeding freely on the foliage. Of the 561 beetles from the 14th to 24th consignments, 361 were liberated between 25 November 1931 and 7 February 1932 in one room, and 200 in the other between 8 January and 6 February.

In August 1932 periodic examinations were begun of all blackberry canes in the room of the double insectary where 361 beetles had been liberated, but no canes were attacked. In the room where 200 beetles had been liberated a preliminary examination of a few canes in December 1932 revealed three larvae in one cane and two in another, but none in any other living canes examined. However, in some dead canes, though larvae were absent, there were typical borings for about 5 in., either directly, or spirally, down to the crown before ascending, yet the crowns of such canes continued to send out new and vigorous growth. A year later, in December 1933, an examination of all the remaining canes in the room revealed a general infestation associated with a regeneration of infested plants.

INFESTATION TESTS

Infestation tests were made on raspberry, loganberry, *Rosa canina*, *R. simplex*, *R. manetti*, and *R. laxa*, but though oviposition took place there was no larval infestation. On the other hand, it was found that the beetles fed freely on the foliage of raspberry, loganberry, strawberry, and apple and to some extent on that of plum, peach, and cherry.

Even if the larval attacks by *Coraebus* were confined to blackberry (as the studies indicated), and if the weed were so controlled (which is doubtful), the fact that the beetles could quite possibly defoliate valuable plants would rule out their use, because if blackberry was to be controlled the insect would have to be present in epidemic force.

OTHER INSECTS

When the blackberry control investigations were initiated, some insects other than *Coraebus rubi* were imported; but the work on them was eventually discontinued.

Bembecia marginata. In December 1926 and May 1927, consignments of blackberry canes, having the crowns infested by the larvae of this moth, were received from Washington, D.C. The material was planted in an insectary under normal atmospheric conditions and began to grow. Toward the end of December 1927, a male and later a female emerged; the former died without copulating, and the female laid 70 infertile eggs. Throughout January 1928 six more females emerged, and four males on the last day of January. Of these, only two males and two females were available at any one time, but no fertile eggs were laid even though pairing had taken place. The experiments with this insect ended here.

Agrilus ruficollis. During December 1926 a consignment of blackberry infested by the larvae of this beetle arrived from Washington, D.C.; the plants were planted out in an insectary and grew rapidly. Only two beetles emerged during the following March (1927), though the remains of larvae were found when all the canes were finally opened.

In January 1931 a second consignment reached Nelson. Approximately one quarter of the material was planted in an insectary just after arrival, as there was a possibility of beetles emerging early enough for experiments to begin. During April, 10 beetles appeared, but they were very lethargic owing to the low temperatures then prevailing; they became more active when removed to the heated glasshouse. No mating or oviposition occurred, even though there was an equal number of sexes, as discovered when the beetles were dissected after death.

The remainder of the material was planted out in April, having been held in cool store in order to prolong the insect's development by about two or three months so that beetles would emerge at a time when seasonal conditions would be more favourable. Towards the end of September 34 beetles emerged and were placed in mating cages. Copulation occurred, and 13 pairs were isolated on blackberry canes. No oviposition took place, and the experiment was discontinued.

Thyatira batis. A consignment of 78 pupae of this moth was received from England in December 1926, and during the following January (1927) and early February 52 moths (22 males and 30 females) emerged. The pupae had been collected in England during November, so were wintering during transit; yet, on being exposed to the late summer and early autumn of New Zealand, moths emerged from them just before the completion of their normal hibernation.

The moths oviposited, and 340 larvae were secured; these were used for tests on raspberry, loganberry, and strawberry with positive results

on all but strawberry. Some 64 New Zealand reared pupae were carried through the winter of 1927, but only eight moths developed in the spring. After some attempts to maintain the insect, the work with it was discontinued because of its omnivorous habits.

Perrisia plicatrix. A consignment of 2,000 pupae of this European leaf midge was received in November 1928 and gave rise to 12 midges of which nine were females. The work was abandoned and the consignment destroyed because the larvae attacked raspberry foliage and because too little was known about its host range; further, owing to its small size, the risk attached to handling it was too great even under the conditions of quarantine operating at the time. A consignment of the European gall midge, *Lasioptera rubi*, was also sent, but was destroyed for the same reasons.

Diastrophus rubi. No attempt was made to investigate this European stem-gall chalcid. Through a misunderstanding an unauthorised consignment was sent, but it was destroyed on its arrival in January 1931.

GORSE

Ulex europaeus L.

INTRODUCTION

Gorse is widely established throughout New Zealand. The species is *Ulex europaeus* L., but Alan (1940) stated that *U. galli* Planch. occurs at Tauranga where it is apparently hybridising with *U. europaeus*, while a "similar but stouter plant, at present not definitely identified, is common in parts of Central Otago". In correspondence (1929) Allan referred to two main types of gorse that are common in New Zealand—a dense short-spined one and a more open long-spined form, between which are several distinct varieties differing in taxonomic details; forms resembling these two types have been found in England. A. S. Watt, in correspondence from the Farnham Royal Laboratory, 1929, stated that there were three species of gorse in England, *Ulex europaeus*, *U. galli*, and *U. nanus* (minor), and noted that *U. europaeus* shows several morphological varieties, *U. galli* occurs on heath in western England, and *U. nanus* (minor) is common at Farnham Royal and in south-eastern England.

Though gorse is one of the major weeds in New Zealand, it is of value as a quick fence and shelter for stock especially on the exposed plains of Canterbury, the young plants have a limited use as fodder, and the plant is beneficial to the soil. When the biological control of gorse was inaugurated, the value of the plant as a quick fence was the main factor in deciding not to attack the plant as a whole but to limit its spread; consequently only insects attacking the flowers and seeds were considered. This approach made a knowledge of the flowering, fruiting, and seeding of the plant essential to any work on the acclimatisation of insects associated with it.

PHENOLOGY OF GORSE

A general picture of gorse phenology in New Zealand was gained from a tentative survey in different districts from North Auckland to Southland.

Flowering, Fruiting, and Seeding. It was found that there are two dominant flowering periods—a minor one from February (in early autumn) until May (in early winter), and a major one from July (in late winter) until December (in mid summer), the periods of fruiting and seeding being about two months after the beginning and ending of the flowering periods; these periods can be earlier or later by one month or so according to locality, and even in the one locality

according to seasonal variations, so the position can vary annually. Furthermore, the picture can be confused in all localities by the exceptional and sporadic flowering and fruiting of some plants between the two dominant periods; such exceptional plants, on being located, were invaluable when insect consignments reached New Zealand between the two flowering periods, particularly during December, January, and June.

A. S. Watt (in correspondence, 1929) stated that in England *U. europaeus* normally flowers from April (late spring) to June (mid summer), but that sporadic flowering occurs from October (late autumn) onwards throughout the winter and that *U. galli* and *U. nanus* (minor) flower from July (late summer) to November (early winter). So apparently the position is seasonally much the same in both New Zealand and England in that the minor and major periods terminate in winter and summer respectively, though in New Zealand the minor commences later, and is of shorter duration than in England, while the major commences earlier in the former country and is of longer duration than in the latter.

However, the whole problem of the behaviour of all species and varieties of gorse requires adequate study before a definite picture can be obtained. A graph based on the available New Zealand data is very misleading; it conveys the impression that gorse is blooming continuously from early autumn to mid summer throughout New Zealand, because the records of exceptional and sporadic blooming of localised plants were not segregated from the blooming of the two major periods. Nevertheless, it sometimes happened, when the minor flowering period was prolonged, or the major was early, that the two periods overlapped, and so presented an unusual and continuous period of flowering, as seems to occur in North Auckland.

Seed Production. No comprehensive survey has been attempted to discover the number of seeds produced in gorse pods. Such a study would require to be Dominion wide and would involve the collection of pods at regular intervals from selected areas under different conditions during a complete year at least; it would also require a knowledge of gorse species and varieties and of insect pollinators under seasonal and district variations. Furthermore, there is a current belief that there exists a seedless variety of gorse. During the research on biological control, bushes were found that produced pods all of which were seedless. Also, Mr. E. W. Valentine of the Division of Entomology (pers. comm.) had in the garden of his home at Bluff an ornamental gorse bush that flowered profusely but did not seed; the flowers were double, and the bush had been propagated from cuttings taken from a hedge that did not fruit.

A thorough survey was not made, but series of pods were examined when circumstances allowed. These records, though meagre, indicated that there is probably an increasing and decreasing sequence in seed production through both flowering periods. It is obvious, however, from experience over the years, that fewer seeds are produced during

the minor flowering (autumn) than during the major one (spring-summer); this is to be expected not only because of the more favourable seasonal conditions during the latter period, and because of its longer duration, but also because there are greater populations of pollinating insects present at that time. The average number of seeds per pod ranged from 0 to 2.65 during the minor flowering; in the major flowering period a general increase from late winter to summer was indicated by the fact that in one series of observations the average in July was 2.43, in August 3.16, in September 3.77, in October 3.52, in November 4.8, and in December 3.8; the number of seeds found in pods during the major period in New Zealand ranged from one to nine, compared with four to seven as recorded in England by Davies (1928a).

INSECTS OF GORSE

The only insects of importance that damage gorse in New Zealand are the cottony cushion scale, *Icerya purchasi* Mask., and the native longicorn beetle, *Oemona hirta* (F.). Severe outbreaks of the scale occur on rare occasions, when the weed is temporarily checked, and even killed, over considerable areas, but the insect is soon controlled by the ladybird beetle *Rodolia cardinalis* (Muls.) and the larvae of the fly *Cryptochaetum iceryae* Will. The last notable outbreak of the scale occurred near Christchurch in 1941. The larvae of the longicorn beetle are fairly common in the stems, particularly of older gorse plants, and at times cause noticeable damage.

The search for insects that attacked the flowers and seeds of gorse was confined to Great Britain and Europe. It was found that several insects inhabited gorse, but their bionomics were unknown; others attacked gorse flowers and seeds but had a wider range of hosts among the Leguminosae. The number of species from which a selection could safely be made, in the light of current information, was thus restricted to the following few; all of them occur in Europe, and at least the Lepidoptera, Diptera, and *Apion ulicis* extend to Great Britain.

Coleoptera	<i>Apion lemovicinum</i> Hoff.	Destroys seeds in pods
	<i>Apion pseudogallaecianum</i> Hoff.	
	<i>Apion ulciperda</i> Pand.	
	<i>Apion ulicis</i> Forst.	
Lepidoptera	<i>Depressaria costata</i> Haw.	Destroys flowers
	<i>Laspeyresia ulicetana</i> Haw.	Destroys seeds in pods
Diptera	<i>Asphondylia ulicis</i> Trail	Destroys flowers

All the *Apion* species breed in developing gorse pods and closely follow a similar cycle; of the four species of *Apion*, *A. ulicis* is the only

one recorded in Britain by Kloet and Hincks (1945)*. According to Hoffmann (1958) *A. lemovicinum* breeds in *U. europaeus*, *A. pseudo-gallaecianum* and *uliciperda* in both *U. europaeus* and *U. nanus*, and *A. ulicis* in *U. europaeus*, *U. nanus*, and *U. parviflorus*.

Depressaria costata. The flowers and pods are attacked by the caterpillars, which are also found on *Ilex* and *Genista*.

Laspeyresia ulicetana. The larvae of this moth, which also occurs on *Genista* and *Lotus*, live on seeds of gorse pods accompanied by *Apion ulicis*, the larvae and pupae of which they devour with the seeds.

Asphondylia ulicis. The larvae of this midge form monothalamous galls destroying the flower buds; up to 40% of the flowers consequently fail and all are destroyed in some seasons.

Of the above insects, *Apion ulicis* was the only one selected for experiment in New Zealand, and supplies were secured solely from England. It has the reputation of causing wholesale destruction of seeds. While that opinion is justified, Professor Heslop-Harrison (correspondence) considered that the bulk of the damage was due to the gall midge *Asphondylia ulicis*, which completely destroyed the flower buds. However, at the time, too many difficulties presented themselves in handling the midge under quarantine. Other reasons for concentrating on *A. ulicis* were: (1) there was more known about it than any of the other species, (2) it was not known to attack any legume other than gorse, (3) it was readily available at Rothamsted, where research was carried out in England, and (4) both finance and staff were limited.

APION ULICIS Forst.

DESCRIPTION

The following prescription for the weevil (Fig. 3) has been translated from Hoffmann (1958).

Length 1.8 to 2.5 mm. Body pyriform, black, the dorsal pubescence squamulose, very dense, ash-grey or grey-yellow, sometimes slightly silky, homogeneous or slightly sparse on interstriae 3-5 of the elytra. The antennae (except for the darkish club) and the legs reddish, the meso- and meta-femora and the trochanters usually darker.

Rostrum long, slender, curved, directed beneath the body, delicately and sparsely stippled, shining, a transverse dentiform dilation at the base, almost as long as the head and thorax

**Apion* was imported only from Great Britain. As it is possible that European species other than *ulicis* do occur there, though not recorded and so could have been imported, a random sample of 200 weevils was collected from gorse bushes at Nelson and sent for determination to the Laboratoire de Faunistique Agricole, Paris; M. Ferragu reported only *ulicis* in the sample.

together in the male, and considerably longer in the female. Antennae with club compact and pointed in both sexes, those of the male shorter than of the female, in the former the three last joints of the funicle transverse, and in the latter the scape curved and clearly longer than the first funicular joint, the three last of which being as long as broad. Eyes large and prominent. Head densely punctate. Prothorax as long as broad, barely so in the male, a little more so in the female, margins curved and converging anteriorly, densely punctate, slightly rugose, with or without a basal median furrow. Scutellum very small. Elytra oblong-oval, slightly arched laterally, humeral callus prominent, striae punctate, interstriae not punctate. First tarsal joint a little longer than the second; claws dentate.

The plump, whitish, legless larva (Fig. 4) attains a length of about 2.5 mm, while the pupa (Fig. 5) is much the same colour and length as the mature larva.

BIONOMICS

BRITAIN AND EUROPE

Prior to the New Zealand research on *Apion ulicis* the only information on the life cycle of the insect was provided by the limited observations made by Gourneau (1845, 1847) in Brittany and Normandy, and Perris (1876) in south-west Gascony, and by the more detailed study of Davies (1928b) at Rothamsted, in England, where he had been engaged for the purpose on behalf of the New Zealand undertaking. The following is a summary of these observations.

Davies found that the insects hibernate as weevils on gorse bushes, not in pods; they cannot eat their way out of pods, and perish therein if the latter fail to dehisce. In winter and spring Davies collected pods that had fallen to the ground, and these contained living and dead weevils. Though he did not record the number of pods or weevils, some indication of the position can be gained from an experimental shipment to New Zealand of 270 unopened pods collected in January (late winter), 201 of which contained 83 living and 499 dead weevils. Presumably the weevils in those unopened pods would have been released if the pods had normally dehisced, and would have hibernated on bushes.

The hibernating weevils actively responded to periods of winter sunshine, but did not commence to feed till the end of February (early spring). Fecundation was first noted in March, and mating continued till the end of May (early summer). Davies first observed oviposition in May and stated that it continued into August (early autumn); Perris, however, found weevils ovipositing during February and March (spring) in south-west Gascony, and it is important to note that this happened in New Zealand, but during autumn.

When ovipositing, the female inserted her eggs through a hole made by the rostrum (Fig. 6, 7) in the wall of the young green pod, the

hole closing as the pod developed. From one to 23 eggs were found in a single pod (Fig. 8), and the incubation period ranged between 22 and 30 days.

The larvulae first fed on the seed funicles before piercing the seeds and devouring the contents (Fig. 9). The larvae took between 40 and 50 days to develop and finally enclosed themselves in gelatinous cocoons, sometimes within the seed coat, and pupated. After eight to 12 days the weevils emerged and remained in the pods until the latter ripened and dehisced (Fig. 10).

Since the life cycle from egg to adult varied from 70 to 92 days, as observed by Davies, weevils would have appeared between about mid July (late summer) at the earliest, and early November (early winter) at the latest; furthermore, Davies recorded that pupae predominated in pods in late July and in August, and that only a few occurred on 9 October, and Gourneau found weevils in pods on that same date. Therefore, it seems that the summer cycles in England, Brittany, and Normandy coincide.

On the other hand, Perris noted that a generation of weevils appeared in south-west Gascony when pods dehisced during May, that is within some 20 weeks from when he observed oviposition in February and March; but the duration of the cycle cannot be assessed as there was nothing to indicate when the weevils had emerged from the pupae within the pods.

Apart from the unopened pods he had collected in winter and spring, Davies found dead weevils in unopened pods during April and May (late spring and early summer), and those insects may also have been of a pre-winter generation, yet they could have developed from a spring infestation if such occurs in England; again, in May 1927, he secured living weevils from a sample of what he called "old unopened pods", but he did not indicate whether the sample had been taken from bushes or collected from the ground, though he concluded that the weevils were "obviously from the 1926 generation", which could be so since it was found in New Zealand that the life span of the weevil can be of considerable duration. Nevertheless, considering Perris's record of a generation arising in May from a spring infestation in south-west Gascony, and the occurrence of a similar infestation of pods in New Zealand (but in the autumn), it is possible that the same occurs in England and that some of the consignments included weevils from a spring generation.

The number of weevils per pod recorded by Davies was from one to 16 (in New Zealand 17 were found in one imported pod), with an average of 4.6; he also found that all the seeds had been destroyed in 69.4% of a series of pods examined. In New Zealand the weevils ranged from 1 to 19 per pod, with an average of 6.0. The highest percentage of seed destruction so far recorded has been 98.67% while 80% and 60% are common enough, though in some situations, and during different periods in the one situation, the percentage is much lower.

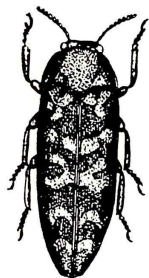


FIG. 1. *Coraebus rubi*;
length 8–10 mm. (After P.
Génieys, 1927.)

FIG. 3. *Apion ulicis* male;
length 1.8–2.5 mm. (After
M. Davies, 1928b.)



FIG. 2. *Coraebus rubi*; lar-
val damage to blackberry
cane. (W. C. Davies photo.)

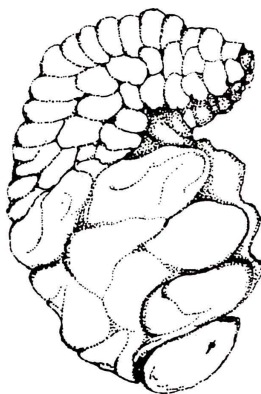
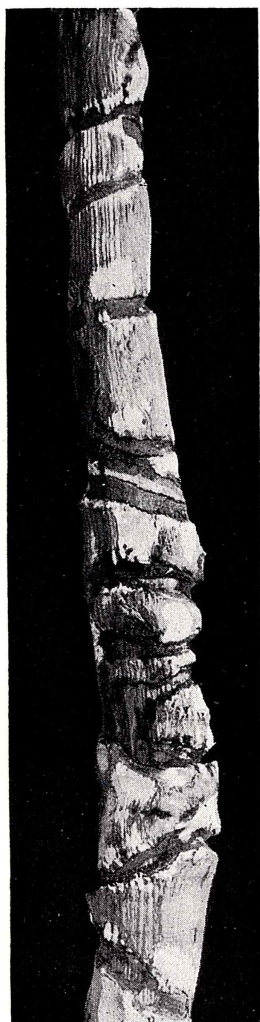


FIG. 4. *Apion ulicis*; larva.
(After M. Davies.)

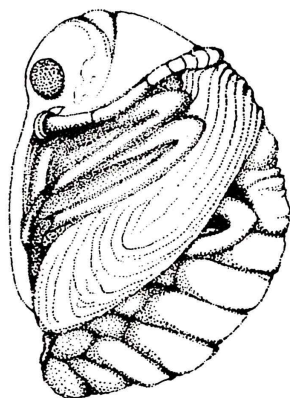


FIG. 5. *Apion ulicis*; pupa.
(After M. Davies.)

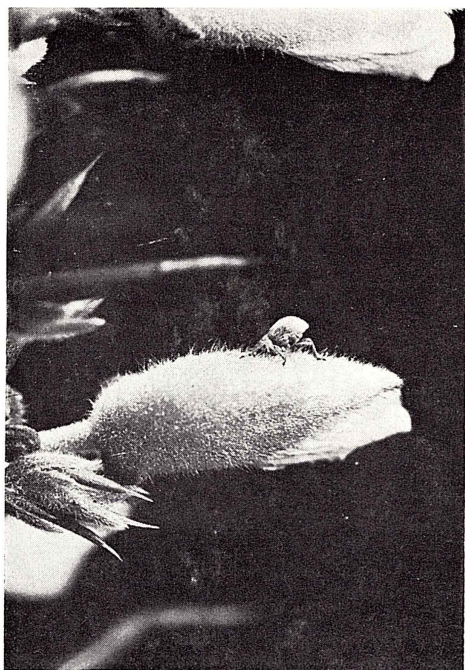


FIG. 6. *Apion ulicis*; puncturing gorse pod. (After M. Davies, 1928b.)



FIG. 7. *Apion ulicis*; ovipositing in gorse pod. (After M. Davies, 1928b.)

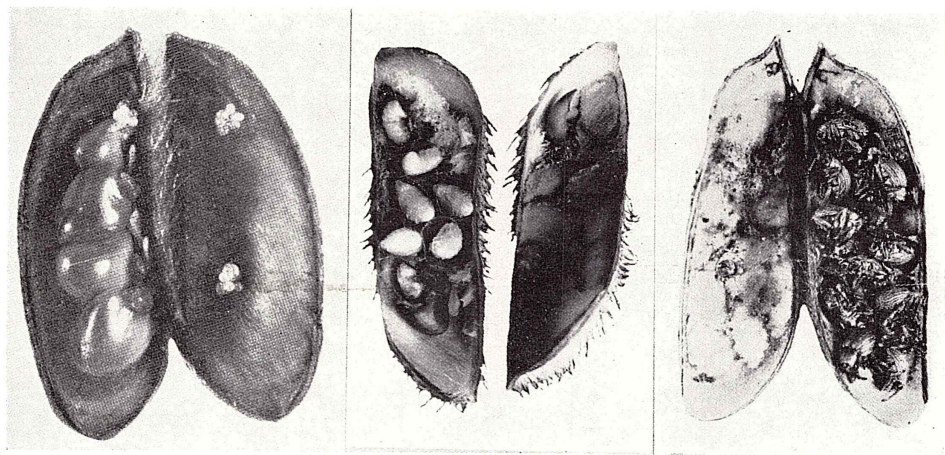


FIG. 8. (left) Opened gorse pod showing seeds and egg clusters of *Apion ulicis*. (After M. Davies, 1928b.)

FIG. 9. (centre) Opened gorse pod showing larvae and pupae of *A. ulicis*. (W. C. Davies photo.)

FIG. 10. (right) Opened gorse pod showing *A. ulicis* weevils. (After M. Davies, 1928b.)

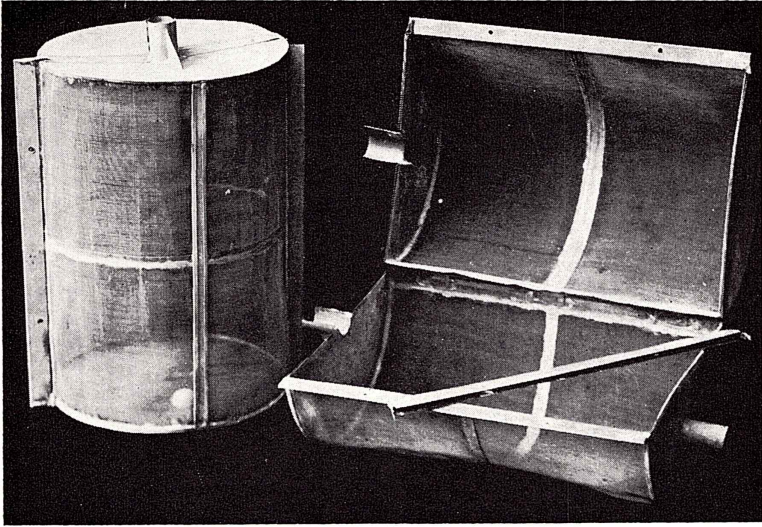


FIG. 11. Drum cages opened and closed. (W. C. Davies photo.)

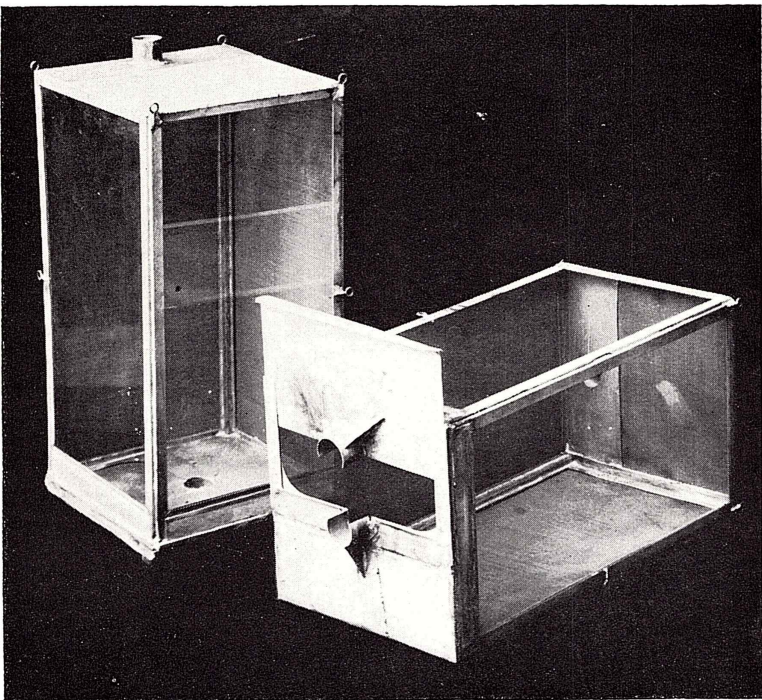


FIG. 12. New type of rearing cage. (W. C. Davies photo.)



FIG. 13. New type of rearing cages enclosing gorse.
(W. C. Davies photo.)

The parasites recorded as having been reared in England from the pre-adult stages of *A. ulicis* are: *Splintherus leguminum* (Ratz.), *Semiotus brevipennis* Walk., *Pteromalus pirus* Walk., *P. micans* Ol. and *Eulophus ulicis* Perr., all of which occur in Europe. Also, of two species of cecidomyid larvae found in infested pods imported to New Zealand from England, one appeared to be parasitic.

NEW ZEALAND

The following summary of the bionomics of *Apion ulicis* in New Zealand is based on the results dealt with under the heading "Studies in New Zealand".

Life Span of Weevils. Apart from those that early fall victim to the normal hazards of life, it was not unusual for the insects to live for 12 months; but it was found that a few could survive much longer and that the progressive mortality was lower among females than males. In assessing the life span the approximate time when the weevils would be released from the pods is taken as a basis, though the insects would have developed much earlier from the pupae and remained in the pods until dehiscence.

In one consignment (4th) collected in England during February 1928, immediately following the winter, five females were still alive in March 1929 in New Zealand; so they had not only wintered prior to being collected but also passed through another winter in New Zealand. Those survivors had possibly emerged from pods during October 1927, or even earlier, in which case their life span had been at least 18 months; alternatively they could have been of a generation that had developed later than October, emerging even in winter, as happens in New Zealand, though there are no records of winter emergences in England. A less problematical case was furnished by the 14th consignment, the weevils of which had been collected in August 1929, during the English early autumn; in New Zealand during December 1930, there were 74 survivors (six males and 68 females), and some of those were alive in February 1931. As the latest date when those weevils could have emerged from pods was August 1929, their life span was 19 months at least.

Influence of Temperature. Weevils occur on gorse bushes throughout the year, and there is no true hibernation. They react to temperature fluctuations, whether natural or induced. Under feral conditions they have been found to reproduce during winter in New Zealand—it may be noted that the 3rd consignment, which had been collected in the late English autumn, reproduced in the New Zealand autumn after wintering seven weeks during transit. In consignments collected whilst the insects were actively reproducing during spring and summer (e.g. 5th in part, 13th, and 19th), reproduction took place when they were subjected to normal conditions after an out-of-season period of some seven weeks in cool store (approximately 40 deg. F) during transit.

The effect on *Apion* weevils of prolonged submission to cool store conditions is not known. Data derived from the consignments are contradictory; for instance, weevils of the 1st consignment, collected during the late English autumn and held in cool store for four months (including their normal wintering), produced a generation in the New Zealand autumn, while those of the 22nd consignment, collected during mid-autumn and subjected to the same conditions, but for five additional months, all perished. Though the mortality in the former consignment was high (77.6%), the absolute mortality in the latter need not have been due solely to the additional month in cool store.

Sterility. Apparent sterility of females was common, the percentage being very high at times; but to what extent that condition is normal is unknown. The influence of light was an obvious factor, as was noted in the higher rate of reproduction in the glass-sided cages, which replaced the gauze-covered drum cages from which so much light, especially sunlight, was excluded (see "Rearing Technique"). Furthermore, when gorse was enclosed in drum cages, many plants withered and no pods formed. Under such circumstances either no eggs matured, or the ovaries remained undeveloped in all females, though some had been fecundated. On the other hand, in nearby cages containing weevils of the same consignment, and in which the plants remained healthy with developing pods, reproduction took place.

Productivity. In England, Davies (1928b) recorded that pod infestation occurs from early summer to early autumn and that the actual life cycle ranges from 10 to 13 weeks; thus weevils would be produced into October (late autumn) or November (early winter) at least, though it can be assumed that development would be retarded with the advance of the seasons. Davies makes no reference to a spring generation, but in view of such occurring in Gascony (Perris, 1876), and of the evidence from the New Zealand research, it is quite possible that a spring generation occurs in Britain as it does in Europe.

In New Zealand, generations (from imported weevils, and also in the field after the insects' establishment) developed in all seasons, and the life cycle (assessed from the time of pod infestation to the removal of the insects from mature pods) lay between eight and 10 weeks, irrespective of the season, the actual period doubtless being less as it was not known when the weevils emerged from the pupae in the pods.

Consignments collected in the English autumn (August, September, October) did not pass a normal winter, but were subjected only to an out-of-season period in cool store during transit; they were received at the close of the New Zealand spring and during summer. Three of these consignments (1, 3, 8) produced a generation in the New Zealand autumn, corresponding to what Perris found in the European spring. Furthermore, dissections made on and shortly after arrival in New Zealand, revealed that females had been fecundated and that the gonads were mature, or were maturing, so that fecundation and

maturation must have occurred before or in transit during the period of the English autumn.

From consignments collected in the English winter (November, December, January), and received during the New Zealand summer and autumn (January, February March), not only were autumn generations produced (corresponding to the English spring), but also winter and summer ones (English summer and winter respectively). Dissections of females from two consignments (2 and 11 collected in January) on their arrival in March (mid-autumn), revealed fecundation and maturation of gonads, which had occurred either before or during transit. Davies (1928b) found that neither fecundation nor maturation had taken place in 500 females collected in England in autumn and winter.

Of four other winter-collected consignments, the percentages of fecundation and maturation in one (10, collected in December) was high in March, and pods infested by females of that consignment contained half-grown larvae in mid winter, but those larvae developed no further; consignments 2 and 11 collected in January were similarly infested, but the larvae reached only the first instar. Under field conditions during winter, first instar and mature larvae together with pupae were found, probably from an autumn infestation; nevertheless eggs occurred in May, pupae in June, and adults, larvae, and pupae in the pods in July at the close of winter, which revealed a winter generation. On the other hand, the fourth (18) consignment collected in winter (January) produced not only a complete autumn generation, but also a summer one after wintering in New Zealand; it is unlikely that the same parents produced the two generations, but the subject requires elucidation. Another consignment (16) collected in England during November produced no autumn generation, but a summer one after the New Zealand winter.

The consignments collected in spring and summer (4, 5, 12, 13, 19, 20, 21) all contained weevils that would have been about to reproduce, or were actively doing so, and so had been subjected to an out-of-season period in cool store during transit; they were received in New Zealand during late autumn and in winter. From only three of these consignments were generations reared; one (19) collected in March (spring), produced a generation in December, the second (5) collected in April (also in spring), a generation in October, and the third (13) collected in June (summer), a generation in December. The four other consignments of this group gave negative results, the weevils being sterile except in one (12) collected in February (spring), in which fecundation and maturation occurred in July during the New Zealand late winter—a matter of interest in that mating and oviposition in the earliest pods, which had formed one year in July, had been observed in the field.

Though the New Zealand-reared generations, irrespective of whether they had appeared in autumn, spring or summer, produced only summer (December) progeny, the foregoing summary shows that the seasonal reproduction by imported weevils corresponds with what is

known to occur in the European and British spring and summer. That this was not due to the insects reproducing according to their normal times during the first seasons of adjustment to New Zealand conditions is revealed by the fact that the habit has continued over several years after establishment in the field. Thus it appears that the timing of reproduction (irrespective of antithetical seasons) has remained much the same in New Zealand as in Europe and Britain, as also does gorse phenology.

METHODS OF SHIPPING

In the course of importing gorse weevils from England from 1926 to 1932, two experiments were made in sending weevils at ordinary temperatures, but of the 9,000 insects involved only one survived. All other shipments were sent in ships' vegetable chambers at an approximate temperature of 40 deg. F.; in that way 311,280 weevils were shipped, and 84,767 of them survived.

The containers were insect-proof, ventilated, wooden boxes of convenient size. The weevils were placed in them either free, or among damp moss (previously sterilised), or were placed in muslin bags surrounded by moss; some bags contained a gorse twig, the end of the bag being sealed or open. Apparently none of these packing methods had any particular advantage in relation to weevil survival, which varied irrespectively; probably a factor influencing survival in transit had been the season when the insects were collected. However the use of muslin bags, with or without twigs, was the method finally adopted; it was the most convenient for transporting the weevils and handling them on arrival.

The weevils for most of the consignments were collected in England directly from gorse bushes, which entailed a careful re-check in New Zealand to guard against any unwanted insects that could have been accidentally included. To reduce this hazard it was decided to send a trial shipment of unopened pods. Of the 270 pods in that experiment, 201 contained 582 weevils of which only 83 were alive; the maximum number in a single pod was 17 and the minimum one. A few living specimens of the chalcid parasite *Splinterus leguminum* Ratz., were present (five adults, one pupa and two larvae), and five pods contained tortricid larvae and pupae (*Laspeyresia ulicetana* Haw.), as well as the larvae of two cecidomyid species one of which was apparently parasitic; in one pod there was a small nitidulid beetle that probably had entered through a chalcid exit hole, and in 63 pods all but 10 seeds were mouldy and shrivelled. Because of these results the importation of infested pods was abandoned. However, as the time approached for the field liberation of *Apion*, and as the rearing of supplies from imported material had proved to be too slow and uncertain under quarantine, the final consignments were of weevils collected from pods in the laboratory at Rothamsted. In that way there was little, if any, chance of insects other than *Apion* being shipped, and quarantine precautions in New Zealand were greatly simplified.

CONSIGNMENTS

Table 5 is a list of all the consignments received from 1926 to 1932, showing the month in which they had been collected in England, the date of their receipt in New Zealand, and data on the survivals.

Disregarding consignments 6 and 17, sent at ordinary temperature, and 22, which had been held in cool store for a long time, the mortality among the imported weevils was variable, but high except for consignments 7, 8, and 26. A high mortality is doubtless normal as was found when rearing the insects in New Zealand, though the enclosed conditions during transit and the out-of-season low temperatures at times were probably adverse factors for weevils in the consignments.

TABLE 5. *Apion ulicis*.

Consign- ment	Date		Number of Weevils		
	Collected	Received	Despatched	Survived	%
(a) Collected from bushes in the field					
1	Oct 1926	14 Dec 1926	3,000	672	22.4
2	Jan 1927	20 Mar 1927	2,000	950	47.5
3	Oct 1927	20 Dec 1927	5,600	1,320	23.56
4	Feb 1928	3 Apr 1928	5,000	944	18.9
5	Apr 1928	12 Jun 1928	7,000	2,667	38.0
6	May 1928	15 Jul 1928	2,000	0	(sent ord. temp.)
7	Aug 1928	14 Oct 1928	2,000	1,500	75.0
8	Sep 1928	3 Nov 1928	4,000	4,171	97.0
9	Nov 1928	3 Jan 1929	4,520	2,892	64.0
10	Dec 1928	28 Feb 1929	5,400	2,151	39.8
11	Jan 1929	29 Mar 1929	6,000	3,084	51.4
12	Feb 1929	1 May 1929	3,500	1,382	39.5
13	Jun 1929	26 Jul 1929	11,000	1,873	17.0
14	Aug 1929	19 Oct 1929	13,000	1,643	12.6
15	Oct 1929	4 Dec 1929	14,000	2,969	21.2
16	Nov 1929	29 Jan 1930	14,000	6,272	44.8
17	Jan 1930	5 Mar 1930	7,000	1	(sent ord. temp.)
18	Jan 1930	26 Mar 1930	14,000	3,786	27.0
19	Mar 1930	8 May 1930	14,000	1,649	11.8
20	Apr 1930	12 Jun 1930	14,000	706	5.0
21	Jul 1930	19 Sep 1930	5,000	618	12.4
22	Sep 1930	12 Nov 1930	11,000	0	(cool store till March)
23	Nov 1930	6 Jan 1931	12,000	424	3.5
24	Jan 1931	19 Mar 1931	12,500	2,715	21.7
25	Mar 1931	21 Apr 1931	16,000	1,720	10.8
(b) Collected from pods in laboratory					
26	Jul 1931	28 Sep 1931	3,960	2,754	69.6
27	Aug 1931	16 Oct 1931	35,144	12,230	34.8
28	Sep 1931	12 Nov 1931	50,956	14,053	27.6
29	Oct 1931	27 Nov 1931	12,000	7,007	58.4
30	Oct 1931	12 Dec 1931	9,000	2,586	28.7
31	Nov 1931	28 Jan 1932	1,700	29	1.7
Totals			320,280	84,477	26.4

Also among insects collected from bushes there could have been a varying number of aged weevils; but that probably had little effect because such weevils would not occur among those collected from pods. However, it is possible that the seasons when the consignments were collected from bushes had some direct bearing on survival, because, by grouping the consignments accordingly, it appeared that the average mortality was higher among weevils collected during spring and summer (when they would be mating and ovipositing) than during autumn and winter (preparatory to, and during, hibernation).

In regard to the weevils from pods, mortality was lowest in the only consignment (26) collected at the end of summer; but those insects would have emerged and overwintered. On the other hand, the four autumn consignments had much the same average mortality as among weevils collected from bushes in the winter. In the single winter consignment (31) from pods the mortality was the highest of all consignments, and a probable reason for this is indicated by Davies (1928b); he found that some pods that had failed to dehisce contained dead, moribund, and active weevils when the pods were opened in winter, so that most of the insects of the particular consignment could have been in a poor state.

STUDIES IN NEW ZEALAND

METHODS

The following records of the bionomics of *A. ulicis* in New Zealand are based on data gathered during the attempts to rear insects from imported consignments and on observations on their behaviour after establishment in the field. The account is sketchy because the insect has not yet been adequately studied in either England or Europe, and could not be under the circumstances in New Zealand.

On receipt of a consignment, both living and dead weevils were recorded, together with the sexes in some instances; by this means, data were secured on mortality during transit in the different seasons (as already discussed), and on the number of insects used at the beginning of each experiment. Further, by counting the insects each time they were recaged, not only was it possible to check whether any had escaped, but the sequence of mortality could be noted, and some indication obtained on the rate of productivity. At times, some females were haphazardly selected and dissected as a lead on the states of fertility. This could give no more than an indication because adequate numbers could not be sacrificed owing to the difficulties of securing reproduction, and the evidence was conclusive only when all the surviving females were examined at the close of an experiment.

The weevils were enclosed on gorse having pods suitable for ovipositing, otherwise on vegetative plants until pods became available. After periodical examinations of both insects and gorse, the weevils were recaged on fresh plants, a procedure followed until the close of the experiment. In some years, during December, January, and February

in particular, and occasionally at other times (such as June, October, and November), flowering gorse with pods suitable for oviposition was not available in Nelson; at such times the weevils had to be held on vegetative plants unless sporadically flowering and fruiting ones were located. Suitable plants were sometimes present in other districts, and in one year a substation was successfully established in Dunedin in December.

Rearing Technique. At first the weevils were enclosed with small gorse bushes within gauze-covered cages; but that very soon proved impracticable. For more critical studies, smaller, "drum cages" were designed so that flowering branches and twigs could be enclosed. These cages (Fig. 11) were of two sizes, measuring 12 and 4 in. in diameter and 18 and 9 in. high respectively. The sides were covered with a fine-meshed phosphor bronze gauze, and the top and bottom were of circular sheets of zinc; the bottom was centrally pierced by a one-inch hole fitted with a metal collar projecting on the outside to surround the stem of the enclosed gorse branch, while on the top, but to one side, was a similar hole closed with a cork after the weevils had been inserted when the cage was in position.

Each cage was constructed in halves hinged down one side, allowing the cage to be closed around a gorse branch. The circumference of each semicircle of the top and bottom was angled downwards and upwards, respectively, so as to give a $\frac{1}{4}$ in. rim to which the upper and lower edges of the gauze were soldered; and along the diameter edge of one top and bottom semicircle of zinc were soldered two strips of metal, which projected to form a slot into which the edge of the opposite half would fit when the cage was closed. The top and bottom halves were each united, at the middle of their circumference and at the extremities of their diameter edge, by strips of zinc 18 (or 9) inches long, and to these strips the gauze was soldered; one pair of these strips at the extremities of the diameter, and adjoining when the cage was closed, was hinged, while each of the opposite pair was angled in such a way as to form a projecting flange, the flanges being locked by a folded V-shaped strip of metal when they came together. Also along the length of the hinged connecting strips a flange was soldered; the flanges on both sides of the cage were pierced by a hole toward each end through which wires were passed for lacing the cage to supporting stakes driven into the ground when the cage was in position. The collar surrounding the stem of the enclosed gorse was packed with cotton wool.

Though drum cages were satisfactory within limits, it was considered that phosphor-bronze gauze shut off too much light, both gorse flowers and the weevil being adversely affected by shade. Measurements showed that when the incidence of the sun was 45 deg., only 28% of the light passed through the gauze, which would be approximately at the end of March and during mid September (mid autumn and mid spring respectively). Consequently a new type of cage was designed and proved satisfactory.

The new cage (Fig. 12) was 18 inches tall and 9 in. square; two adjoining sides were of glass, and the other two, with most of the top, were covered with phosphor-bronze gauze. The bottom was a zinc plate in which was a central hole, $1\frac{1}{2}$ in. in diameter, fitted with a metal collar projecting outwards to surround the stem of the enclosed gorse branch; for the passage of the latter the bottom plate and collar were halved, one half being a permanent fixture forming the base upon which the frame of the cage was built. To this fixed half a 9×9 in. rim was soldered, on the two projecting arms of which were fitted metal grooves on the outside in which the movable half slid to fit into a slot along the edge of the fixed half; when the bottom was so closed the metal collar (the halves of which overlapped) surrounded the gorse stem and was plugged with cotton wool. On the corners of the 9×9 in. rim on the fixed bottom half were attached the 18-in.-long angled uprights supporting similar cross pieces of the top; three of the uprights, and their connecting top cross pieces, were doubled to form a groove to hold the two adjoining sides of glass; these glass sides reached to, and fitted into, a cross piece of zinc one inch short of the bottom of the cage, the intervening space being covered with gauze to give ventilation behind the glass. The other two adjoining sides were of gauze, as was all but 4 in. of the top at one side which was of zinc carrying a collar around a hole for the insertion of the weevils. Half way up the two long angles of the cage where glass and gauze adjoined, and at each corner of the top, an eyelet was soldered by which the cage could be laced to supporting stakes driven into the ground. When in position over an enclosed gorse branch (Fig. 13), the cage was placed with the adjoining angle of the two glass sides directed north so that the maximum of sunlight could be utilised. The temperature in the new cage was higher than in the drum cages, averaging 70.2°F in the former and 65.5°F in the latter for 18 readings at 2 p.m. in the summer, but the conditions proved favourable for both gorse and insects.

CONSIGNMENTS COLLECTED IN AUTUMN — AUGUST, SEPTEMBER, OCTOBER

(Nos. 1, 3, 7, 8, 14, 15, and 22)

August The 7th and 14th consignments were collected in this month and reached Nelson during mid October in 1928 and 1929 respectively.

There being no fruiting gorse at hand during October 1928 the 1,500 survivors from the 7th consignment were caged with vegetative plants until suitable pods became available in February 1929. Dissections in October and December 1928 failed to reveal any fecundated females, and the gonads were immature. In February 1929 fecundation of some had taken place, and the ovaries were developing but not the ova. Toward the end of March all the insects but seven males and 11 females had perished; these females were dissected, but neither were they fecundated nor were the gonads fully developed.

The 1,643 survivors (327 males and 1,316 females) of the 14th consignment were caged on fruiting gorse in October 1929. Dissected females at that time had been fecundated and had developed ovaries, but not ova. In February 1930 no fecundation or gonad development was found, conditions which prevailed throughout the year until the end of the experiment in December 1930 when 74 weevils survived (six males and 68 females); these insects were caged on vegetative gorse, but their fate is unknown except that some were alive in February 1931. As the latest date when the weevils of the 14th consignment could have emerged from pods would have been in August 1929 when collected, and as some were still alive in February 1931, the possible life span was over 19 months.

Fecundation had occurred in the 14th consignment by the time it arrived in New Zealand in October, and must have taken place before or during transit, prior to the normal English hibernation. On the other hand, none of the dissected females of the 7th consignment showed fecundation till February, following the normal English hibernation, though it could have occurred in other undissected females.

September Two consignments (8 and 22) were collected in September, and were received in November during the early summer of 1928 and 1930 respectively. As no gorse with suitable pods was available in November 1930, and as field liberations were to commence early in the following year, the 22nd consignment, instead of being caged on vegetative gorse until young pods would be procurable in February 1931, was held unopened in cool store during the intervening five months to ascertain if the constant recaging on vegetative gorse could be dispensed with; but all the weevils died.

The 3,880 survivors of the 8th consignment, however, were placed on vegetative gorse a few days after their arrival early in November 1928; mortality, usually high after removal from cool store, was very low. In mid December 3,000 weevils were alive, and dissected females were fertile and sexually mature; none had been dissected when the consignment was received a month before, so it cannot be said whether the fertility and maturity of the gonads took place before or during transit, or during the month on vegetative gorse. Of the available weevils, 425 were retained at Nelson for observation and 2,565 (1,278 males and 1,287 females) were caged on fruiting gorse at a substation near Dunedin.

The 425 weevils retained at Nelson were recaged on vegetative gorse in mid December 1928 and held there until March 1929, when 329 were alive (143 males and 186 females). Of the several females dissected, 20% had been fecundated. The remainder were placed on fruiting gorse. Examinations were made again in May, and finally in June (winter), when dissections of the surviving females showed that none was fecundated, so that all the ones fecundated earlier had perished. The absence of fecundation and gonad maturity in June was not necessarily due to winter as will be seen when dealing with the behaviour of the insects under field conditions in New Zealand.

At Dunedin, eggs (some just hatching) were discovered in pods by the end of January 1929, seven weeks after the insects had been caged, and three weeks later, in February, there were larvae mostly half grown. At both times (January and February) dissection of females showed that several were fertile, with mature gonads and developing and developed ova; others were unfecundated with undeveloped gonads. Again, during and after a further five weeks to the end of March both fecundated and sexually mature females were present. It was also noted that in cages where no pods had developed (owing to the withering of the plants, as often happened in drum cages), either no eggs had matured, or the ovaries had remained undeveloped by the end of March, though some females had been fecundated.

When the pods were examined during early April, some had been punctured without oviposition (probably for feeding), and others contained *Apion* in the weevil, mature larval, and pupal stages, of which there was a total of 238; the number of infested pods was not recorded, and the average cannot be assessed. Of these *Apion*, 182 were weevils (80 males and 102 females), and the cycle had been completed during autumn within 10 weeks from the time eggs were first observed at the end of January. Infestation of pods in January corresponds with the records of Perris (1876) in south-west Gascony though during reversed seasons.

In the case of the pupae and mature larvae found with weevils in April, weevils could have developed in May from the former, and in June from the latter unless falling temperatures would have destroyed them, though weevils could have survived in unopened pods throughout the winter.

Of the original 2,565 parent weevils placed at Dunedin in December 1928, 1,076 had survived by April 1929, showing a mortality of 58% over some 16 weeks. About 60% of females dissected were fecundated, but none had developing ova. The remaining insects were caged out of doors with fruiting gorse in April. When examined in June (mid winter), from 15% to 18% of the pods had been punctured apparently for feeding; no oviposition had taken place. Of females dissected, 40% were fecundated, but none had developing ova. Recovery of 570 living *Apion* (252 males and 318 females) indicated a further rise in mortality of 47% since recaging during April. The weather having become colder, the 570 survivors were caged in the glasshouse with fruiting gorse from a bush that flowered in late autumn. They were examined again in July, and finally during mid September, by which time all had died and no more pods had been punctured.

October Three consignments had been collected in October, viz 1, 3, and 15; no study was made of the last, the weevils having been used for starvation and preference tests on plants other than gorse.

The 1st consignment reached Nelson in December (1926) during mid summer; no suitable fruiting gorse being available, it was held in cool store until the end of January 1927. When received there were only 672 survivors (mortality 77.6%), and by the end of January

only 105 weevils (mostly females) were alive; it should be noted that this high mortality occurred after the insects had been in cool store for a period during, and but little more than, the normal hibernation.

Mating took place when the 105 weevils were caged on fruiting gorse at the end of January, but the males died soon after and the females four weeks later. By the end of March all the pods in the cage were ripe (not mature), and pupae were found in the few that were opened. Early in April a generation of 110 weevils emerged from the remaining pods, so the complete cycle lay within nine weeks from the time the parents had been placed on fruiting gorse. The number of parent females and the proportion of sexes in the resultant generation are not known.

The 3rd consignment was received in December 1927. As with the 1st consignment, transported under the same conditions, there had been a high mortality (76.4%) during transit, only 1,320 weevils surviving. The consignment was held in cool store until suitable gorse became available in February 1929, and during that time weevils were periodically removed for starvation and preference tests.

When caged on fruiting gorse in mid February, only 333 weevils (44 males and 289 females) were available. Nevertheless, the few mature pods that had developed by mid May contained *Apion* as mature larvae, pupae, and as adults (one male and two females); it is not known when the eggs from which these weevils had developed were laid, except that it was after mid February, so the duration of the cycle cannot be assessed.

CONSIGNMENTS COLLECTED IN WINTER—NOVEMBER, DECEMBER, JANUARY

(Nos. 2, 9, 10, 11, 16, 18, 23, and 24)

November Three consignments (9, 16, and 23) were collected in November at the beginning of the English winter.

The 9th consignment reached Nelson early in January (1929) during the New Zealand summer; it had been shipped in cool store whilst in its normal hibernation period; the mortality during transit was not high (36%).

The 2,892 surviving weevils (there are no data on the proportion of sexes) were retained on vegetative gorse throughout January and February. In mid March the weevils were caged on fruiting gorse. At that time, 1,488 were alive (599 males and 889 females), the mortality having been 48.5% during 10 weeks under caged conditions. Dissection of some females showed that 20% had been fertilised, but the gonads were immature; it was in March that Davies (1928b) first found sperms in the spermatheca.

At the close of June (mid winter) there were 514 living weevils (178 males and 336 females), the mortality during some 15 weeks (partly in winter) having been 64.5%. No oviposition had taken place and infertility was still very high. The remaining 504 weevils

were caged with flowering gorse in the heated glasshouse (approximately at 65 deg. F), and held there till late September, when no males and only 13 females were alive, and none of the pods had been attacked. Three of the females were dissected: in each the spermatheca was empty, in two the ovaries were developed but with no ova, and in one the ovaries were undeveloped. The remaining 10 females, with three males from another consignment, were caged on fruiting gorse; when the final examination was made at the close of November, all the insects were dead without having attempted to oviposit.

The 16th consignment reached Nelson at the end of January 1930, so the insects had been under natural hibernation during transit; 55.2% died in transit, and the 6,272 surviving weevils (2,354 males and 3,918 females) were placed on vegetative gorse.

At the beginning of March the insects were transferred to fruiting plants, at which time there were 2,771 living weevils (707 males and 2,064 females), the mortality, particularly high among the males, having been 55.8% during about five weeks. No pod infestation had occurred by the close of May, when 2,004 weevils had survived (531 males and 1,473 females) giving a mortality of 27.8% within some 12 weeks. The survivors were recaged and examined again at the end of July (close of winter); there were then 1,799 alive (465 males and 1,334 females), 10.2% having died during nine weeks; these survivors were caged with gorse in bloom. At the next examination at the beginning of October no pods were infested and 431 weevils were alive (107 males and 324 females), the mortality having been 76.0% during nine weeks. The 431 weevils were placed on fruiting gorse, and in the first week of December a generation of 73 weevils (34 males and 39 females) was counted; therefore, the life cycle lay within nine weeks during late spring and mid summer, as compared with 11 ($\pm$) weeks recorded by Davies (1928b) in the late spring and autumn of England. It is to be noted that reproduction did not immediately follow the normal English period of hibernation, when the insects were in transit, but occurred after another hibernation in New Zealand.

The 23rd consignment was received early in January 1931 during the New Zealand summer, and had been in transit during the normal hibernation period, though this had been shortened to nine weeks; there were only 424 survivors (21 males and 403 females), the mortality of 96.5% being very high. The living insects were immediately caged on vegetative gorse.

Since a permit was obtained in February 1931 for the field liberation of *Apion* reared in New Zealand, together with those collected from pods in England, the survivors at periodic examinations of the 23rd consignment were eventually brought together during March and April with those of the 24th and 25th respectively; consequently these consignments were not specifically studied. However, the ultimate survivors of the three consignments were finally caged on fruiting gorse during October, and by December a generation of 378 weevils

(147 males and 231 females) had developed. The extent to which any of the consignments contributed is unknown, but it can be noted that the weevils had passed an English and a New Zealand winter before progeny were found, as happened with the 16th consignment.

December The 10th consignment, the only one collected in December, reached Nelson at the end of February 1929, and had been under winter conditions for one month beyond normal hibernation. The mortality during transit was comparatively high (60.2%), the survivors numbering 2,151.

The insects were placed on vegetative gorse. A month later, at the end of March, only 368 weevils (85 males and 283 females) were alive, 83% having died. Dissections of some females revealed that 80% of them had been fecundated; of these, 40% had fully developed ovaries, and the ova showed signs of healthy development in the remainder.

The 368 weevils were enclosed with fruiting gorse. At examination in mid May and mid June pod infestation was high; in mid May 60% of the pods examined contained eggs, 20% larvulae, and 20% half-grown larvae, while in mid June 7% contained eggs, 53% half-grown larvae, and 38% dead larvae. The percentage of fecundated females among those dissected was as high as 80%.

It being then mid winter, the remaining insects were transferred to fruiting gorse in the heated glasshouse (approximately 65 deg. F), but they were all dead by September and no pods had been attacked.

Weevils of the 10th consignment were fecundated and had matured by the end of March (as they do in England after normal hibernation), and from the May and June records, they must have infested pods at the beginning of April, though they had developed only to half-grown larvae in mid winter; as all the available pods had been sacrificed for examination, it cannot be known how far the insects would have developed.

January Four consignments, the 2nd, 11th, 18th, and 24th, had been collected in January: of these, the 24th was not studied specifically as mentioned in the account of the 23rd (see under *November*).

The 2nd consignment reached Nelson toward the end of March 1927 during the New Zealand mid autumn, the insects having been submitted to about seven weeks in cool store during transit in addition to their normal period of hibernation. There had been a mortality of 52.5%, and the 950 survivors were caged on bushes with suitable pods. The insects oviposited at the end of March, immediately after being caged after arrival, and during April (in the same months, but opposite seasons, as in England). As pods matured they were collected for examination up to mid September; in most of them the eggs had not hatched and were decayed, but in the few pods in which eggs had hatched only the shrivelled skins of larvulae were found; there was no development beyond the first instar. Thus, reproduction in the 2nd consignment followed much the same course as in the 10th.

The 11th consignment was received at the end of March 1929 during the New Zealand autumn, after eight weeks in cool store during transit following normal hibernation; 3,084 weevils survived, 48.6% having perished.

From dissections made of a number of the females, it appeared that some had been feeding during transit, even under cool store conditions. Another striking feature was that 20% had been fecundated. Though Davies (1928b) found no pairing before winter in England, it is to be assumed that it did occur in this consignment, at least during the eight weeks' transit in cool store at about 40 deg. F following normal hibernation; also, the ovaries of the fecundated females were more or less developed.

The remainder of the 3,084 survivors were placed with flowering gorse at the beginning of April just after arrival, and in mid June 18% of the pods contained larvae. The surviving 655 weevils were transferred to cages in the glasshouse and there remained over winter until mid spring; when examined towards the end of September, all were dead but two females, and no pods had been attacked. The spermatheca of each female was empty, but the ovaries were well developed and ova had been forming in one specimen.

The 18th consignment reached Nelson at the end of March 1930 during mid autumn, after about eight weeks in cool store in transit following normal hibernation. The mortality was 73%, and the survivors numbered 3,786 (1,237 males and 2,549 females); these were placed on fruiting gorse at the end of March, and when examined about nine weeks later during the last week of May, 1,246 weevils were alive (227 males and 1,019 females), and an early winter generation of 110 insects (45 males and 65 females) secured from the pods, so the life cycle lay within nine weeks.

As no fruiting gorse was available, the surviving 1,246 parent weevils were recaged with vegetative plants at the close of May, and were examined at the end of July, by which time 1,070 weevils were alive (210 males and 860 females); these were recaged on vegetative gorse, and again on fruiting gorse on 7 October. On 3 December another generation of 35 weevils (19 males and 16 females) was secured, and 372 parents were alive (51 males and 321 females); the latter were again caged, but there is no record of their fate. The second generation (the life cycle of which was within eight weeks), with the first, was caged for the purpose of field liberations, which commenced early in the following year.

The experiments with the 18th consignment presented some very interesting features. The parent weevils had been collected during January 1930 whilst hibernating, which period had been prolonged by some eight weeks in cool store during transit. By the end of May in the early New Zealand winter, a generation had been produced by some of the 3,786 weevils that had survived; 67.1% of the latter had perished by the close of May, 1,246 remaining alive. By the end of July (late winter) 14.1% of these had died, leaving 1,070 from

which another generation had developed by 3 December; from the close of July until early December 65.2% of the parents died, leaving only 372.

It is not known whether the December progeny had been produced by any of the same parents that produced the first lot in May (and there was a high mortality among them at that time), but, if so, it would mean that the insect had two sets of progeny, the second following another winter. On the other hand, the two lots of progeny could have been derived from separate lots of parents; this is a subject that requires elucidating. Another feature is that the life span of the ultimate survivors of the consignment had been at least 15 months.

CONSIGNMENTS COLLECTED IN SPRING—FEBRUARY, MARCH, APRIL (Nos. 4, 5, 12, 19, 20, and 25)

February The February consignments were the 4th and 12th.

The 4th consignment reached Nelson toward the end of autumn at the beginning of April 1928. The insects were coming out of winter quarters when collected in February, and had a further six weeks in cool store before arrival in New Zealand. Mortality during transit was 81.1%, the survivors numbering 944 (44 males and 900 females).

As it was nearly winter, the *Apion* were encaged with vegetative gorse; no pairing was observed. Females were dissected from time to time but none was sexually developed, though they had fed well and their bodies were filled with fat. Feeding took place during the New Zealand late autumn.

By the end of May only 216 weevils were alive (six males and 210 females). Sterility continued and no oviposition occurred in pods exposed to the insects for the rest of 1928. In March 1929 only five females had survived; these were unfertilised with undeveloped ovaries.

Quite apart from the high mortality in this consignment, collected from bushes, and the universal female sterility, it is of note that some females, which had probably emerged not later than the English autumn of 1927, had survived till March 1929 after passing through two winters.

The 12th consignment was collected during February 1929 just after the English winter; it was received in Nelson at the beginning of May (the close of autumn), so had spent eight weeks in cool store during transit. Only 1,382 weevils survived, the mortality having been 60.5%. None of the females examined had been fecundated or had developing ovaries.

The remaining insects were caged with fruiting gorse in the heated glasshouse (approximately 65 deg.F). When the cages were opened during July, only 129 weevils (37 males and 92 females) were alive, the pods had not been punctured, and a dissection of a few females revealed that only 20% of them were fecundated and that all but one had undeveloped ovaries.

The survivors were transferred to a cage over fruiting gorse. When again examined toward the close of September (mid spring) all but 45 insects (five males and 40 females) were dead, and no pods had

been attacked. Five of the females were dissected; one had been fecundated and had developed ovaries and developing ova, one had undeveloped ovaries, and three had developing ovaries but no ova. The remaining 40 insects were caged with flowering gorse, and when examined at the close of November all were dead and no pods had been attacked.

March Two consignments, the 19th and 25th, had been collected during the English mid spring when the weevils were active and reproducing. Only the 19th was specifically studied, the 25th having been placed with the 23rd and 24th (see under the winter-collected material).

The 19th consignment reached Nelson in the first week of May in the early winter after an out-of-season period of seven weeks in cool store during transit. A total of 1,649 weevils survived (38 males and 1,611 females), the mortality having been very high (88.2%), especially among the males. In mid May the weevils were caged on fruiting gorse; by the end of July no reproduction had taken place, and the insects were recaged on gorse with suitable pods; there was no development by the first week of October when the survivors were again caged; by 1 December a generation of 71 weevils was secured (40 males and 31 females), and there were 495 surviving parents (25 males and 470 females), the life cycle lying within eight weeks. The progeny and parents were placed in separate cages, the former to be held for liberation.

April The 5th and 20th were the only consignments collected in April.

The 5th had been collected at the end of the English spring and reached Nelson in mid June 1928 in the New Zealand winter after having been in cool store for an out-of-season period of seven weeks during transit; 2,667 weevils survived, and 62% had perished.

The weevils were placed with flowering gorse in a warmed laboratory at 60 deg. F, and were put out of doors in the sun during the middle of the day when circumstances were favourable. Mating was observed in June (at the same period as in England), and some females dissected in July contained nearly matured eggs.

Many ripe pods collected at the end of September showed signs of punctures, and some contained larvae and pupae. Other pods collected at this time were held until mature and produced a generation of 18 weevils (eight males and 10 females) in mid October. It would seem that the cycle of that generation was a prolonged one, but the records are incomplete.

The remaining parents were caged on gorse with suitable pods and placed out of doors. All the weevils died (the last survivors being four females, which died in December). Many pods had been punctured but there was no oviposition; the punctures could have been for feeding.

The 20th consignment, collected in 1930 at the end of the English

spring, also reached Nelson in mid June after an out-of-season period of seven weeks in cool store during transit. Only 706 weevils survived (two males and 704 females), the mortality having been high (95%) particularly among the males.

The weevils were caged with vegetative gorse on arrival, and males added from other consignments; they were recaged with flowering plants in mid August. By mid October no progeny had developed, and the 253 survivors (25 males and 228 females) were again recaged. Neither pods nor progeny developed before the weevils died in November.

CONSIGNMENTS COLLECTED IN SUMMER—MAY, JUNE, JULY

(Nos. 13 and 21)

June The 13th consignment was received at Nelson in July at the close of winter, and had spent an out-of-season period of seven weeks in cool store during transit. Only 1,873 weevils survived, mortality being 83%.

Of the several females dissected, 50% were fecundated; 60% of these had fully developed ova, the rest partly developed. Of the non-fecundated females, 20% had undeveloped ovaries, while those of the remainder were more or less developed and the ova small.

The living weevils were enclosed with fruiting gorse, and some of the cages were placed in the heated glasshouse (approximately 65 deg.F) and some out of doors.

Towards the end of September, the pods from the glasshouse were opened, but none had been attacked and only 17 weevils (seven males and 10 females) were alive; these were recaged on fruiting gorse in the glasshouse, but all died without ovipositing.

The records for the outside cages are incomplete, but a generation of 82 weevils (36 males and 46 females) was secured in December, so the life cycle was completed within about nine or 10 weeks.

July The 21st consignment had been collected a month later than the 13th, and reached Nelson in mid September 1930 during the New Zealand mid spring after an out-of-season period of seven weeks in transit. Only 618 weevils survived (296 males and 322 females), 87.6% having perished. The survivors were caged with fruiting gorse towards the end of September; at the beginning of December no progeny had developed, and the remaining 493 insects (235 males and 258 females) were recaged, but all died.

HISTORY OF NEW ZEALAND GENERATIONS

Twelve generations of *Apion* were reared in New Zealand from 11 consignments of imported material. In addition, weevils were reared from three consignments (23, 24 and 25) that had been caged together, so it is not known whether these weevils had arisen from one or more of the consignments in question.

Of these New Zealand-reared generations, three (from consignments 2, 10, and 11) did not reach maturity; three (from 1, 8, and 13) reproduced; two (from 3 and 5) failed to reproduce; and the remainder (from 16, 18, 19, 23, 24, and 25) were used for mass rearing and for field liberation. Thus the histories of only five of these generations (from the 1st, 8th, and 13th, and from the 3rd and 5th consignments) are considered here; they are dealt with according to the seasons in which they were reared.

Autumn Reared. (1) From 105 weevils of the 1st consignment, a generation of 110 insects (the proportion of sexes was not recorded) was secured during early April 1926 at the close of autumn, and after some nine weeks from oviposition. These weevils were caged with flowering gorse out of doors; the winter was severe, no pods formed, and mortality was high. On 16 September only 40 weevils survived (13 males and 27 females); they were caged on flowering and pod-forming gorse, when they freely oviposited. Approximately 12 weeks later (20 December) a *second* generation of four females only was secured. The experiment could not be continued with the four females as no males were obtainable.

(2) The 182 weevils (80 males and 102 females) reared in April in 1929 from pods infested by at least some of the 1,287 females of the 8th consignment were enclosed with pod-forming gorse during that month; three of the cages were placed in the heated glasshouse (at approximately 70 deg.F), and two out of doors. On 10 July, all but 10 *Apion* were dead in the glasshouse cages; these survivors were recaged, but all had died by 18 September without having attacked the pods. On that date, 47 weevils were alive (17 males and 30 females) in the out-of-door cages, in which the gorse was flowering and fruiting, but there was no oviposition though feeding had taken place as revealed by the gut contents of six dissected females; in all of the latter the spermatheca was empty, in three the ovaries were developing but contained no ova, and in the others the ovaries had developed and the ova were forming.

On 23 September, the remaining 41 living weevils (17 males and 24 females) were again encaged with flowering and fruiting gorse out of doors in one of the new glass-sided cages; this was the first time that type of cage was used, and it proved its effectiveness. By 30 November 1929 all had died but two males and 11 females. These were transferred to fruiting gorse, and were examined from time to time until 23 May 1930, when all had succumbed without attacking the pods.

On 30 November, when the 13 survivors had been recaged, 122 pods were collected; of these 18 had already opened and had not been attacked, while 50 detached from, and 54 attached to, the plant were unopened. As an examination of some of the unopened pods revealed larvae, pupae, and adults, the remainder were held for observation; from 37 of them, between 30 November and 30 December 1929,

a *second* generation of 224 weevils was obtained (101 males and 123 females), of which 84 males and 113 females were alive.

This *second* generation was recaged with vegetative gorse, and there held until flowers and pods became available. The weevils were examined on 16 January 1930, when the survivors numbered 56 males and 48 females, which were again caged on vegetative gorse. The numbers had further decreased to 21 males and 29 females by 20 May, and to 15 males and 18 females by 8 September; during that period flowers had appeared in the cage but pods failed to develop, probably owing to the exclusion of pollinating insects. On 8 September the surviving weevils were transferred to a cage with flowers in an advanced stage, and on 14 December 1930 12 males and 14 females were still alive, and a *third* generation of 350 weevils (170 males and 180 females) had developed.

Winter Reared. A very small generation was secured in early winter from 289 females of the 3rd consignment. The parents had been caged on pod-forming gorse in mid February. In mid May 284 pods had matured, 20 of which had been punctured without oviposition, and eight contained *Apion* in some stage of development, only three weevils (one male and two females) having developed. These insects were placed on gorse in an insectary exposed to winter conditions, and the male died after seven weeks. Some males from another consignment were supplied, but these died without mating having been observed. In early spring the two females were placed on gorse with young pods, but they died without ovipositing.

Spring Reared. Weevils of the 5th consignment were caged during mid June 1928 in a warm laboratory (60 deg. F), and a generation of 18 weevils (eight males and 10 females) was procured in mid October, when the insects were caged on vegetative gorse at ordinary temperatures; but though so held throughout the summer, no oviposition took place when pods became available in the following autumn (1929). The insects were recaged on fruiting gorse on 14 March, none having been sacrificed for dissection as it was considered best to ascertain their fertility from their oviposition. As none had oviposited by 7 May, one female was dissected; though the ovaries were developed the spermatheca was empty and no ova were forming. The weevils were once more transferred to fruiting gorse on 26 June (mid winter) in the glasshouse, but by 9 July all had died without ovipositing.

Summer Reared. Weevils of the 13th consignment reproduced, but the records are meagre. The insects were caged with fruiting gorse at the end of July 1929, and after they had been recaged from time to time a generation of 82 weevils (36 males and 46 females) was procured in December; these gave rise to a *second* generation in December 1930.

TESTS ON PLANTS OF ECONOMIC IMPORTANCE

In England, Davies (1928b) carried out starvation and oviposition tests, with negative results, on broom, lupin, broad and kidney beans, garden pea, lucerne, and wild white clover. In New Zealand 800 weevils (200 males and 600 females) were used for similar tests, and also for preference tests, on blue, yellow, and regal lupins, lucerne, white, and red clovers, green and sweet peas, broad, French, and scarlet runner beans, native kowhai (*Sophora*), kaka beak (*Clianthus*), and broom (*Carmichaelia*).

The weevils were caged with plants that carried very young and young pods, and gorse with suitable pods was included with the same plants in a series of preference tests. The experiments were carried out from September to March. The results were negative on all plants but gorse, except that some plants of the native broom were nibbled.

It should be noted that the pods of kowhai and native broom are infested by native insects, the former by the larvae of an unidentified moth, and the latter by the larvae of a weevil belonging to the genus *Perisotoreus* (Mr E. S. Gourlay, pers. comm.). The writer has also found the pods of the New Zealand pink broom (*Notospartium carmichaeliae* Hook.) so heavily infested by the larvae of some native species of weevil that few seeds remained intact. Such occurrences could give rise to reports that *Apion ulicis* was responsible.

LIBERATION AND ESTABLISHMENT

During 1930 the research on *Apion ulicis*, including tests with native and exotic legumes (other than gorse), had reached a stage when it was considered safe to commence liberations of the insect.

The rearing of sufficient numbers bred in New Zealand was a very slow and uncertain process; dealing with the weevils under quarantine was a serious handicap and resulted in an extremely high mortality among the survivors from imported supplies. To overcome this difficulty, and as no other species of *Apion* was known to infest gorse in Britain, it was decided to import, for direct liberation, *A. ulicis* weevils that had been collected from pods in the laboratory (consignments 26-31); by this means any insects other than *A. ulicis* were eliminated, the presence of unwanted species having been an ever-present danger with the consignments (1-25) collected from gorse bushes and used for research under quarantine.

Liberation. A permit for liberation was secured on 24 February 1931. The first liberations were with the surviving New Zealand reared weevils, of which there were 560 (281 males and 279 females). They were divided into two lots; one of 281 weevils (140 males and 141 females) was liberated on 25 February 1931 on flowering gorse in the Cawthron Institute plots, and the other, of 279 weevils (140 males and 139 females), on 27 February at Alexandra, Central Otago, where the gorse was in a suitable state of flowering. Maturing pods were

periodically collected from both these areas throughout the year and examined for infestation. The breeding cages containing the survivors of the English field-collected 23rd, 24th, and 25th consignments were examined periodically throughout 1930 and 1931, and from 17 August to 24 November 1931 progeny totalling 378 weevils (147 males and 231 females) were obtained and liberated in the Cawthron Institute grounds.

From 28 September to 12 December 1931 and on 28 January 1932 consignments 26 to 31 of pod-collected *Apion* were received from England; the survivors were liberated as follows:

(1) In November 1931 35,481 weevils (10,117 males and 25,364 females) were sent to Otago and released at Burnside near Dunedin on 16th and 19th, and at Brighton on 20th and 24th. At Burnside gorse was in full bloom with only a small percentage of pods, while at Brighton the flowering was more advanced with a fair percentage of pods.

(2) On 16 November 1931 3,178 weevils (992 males and 2,186 females) were liberated in the Cawthron Institute grounds, and on 2 March 1932 29 weevils from the 31st consignment; the last progeny of 124 weevils (42 males and 82 females) reared in cages from imported parents, were liberated there on 5 May 1932.

Establishment. During 1931 a close watch was kept on the gorse growing in the Cawthron Institute grounds, but none of the weevils liberated during February was found; it was not until 8 November 1932 that larvae were found in two pods for the first time in the field. No further infestation was recorded for 1932; nonetheless during October, November, and December 1933, large numbers of weevils were evenly distributed throughout the plots, and on 12 October pods containing very young larvae were readily found. On the other hand, and in spite of the mass liberations in 1931, no infestation could be found at Burnside and Brighton during 1932, though it noticeably developed later; but as close a watch had not been kept there as at Nelson. By January 1934, three years after liberation in February 1931, the insects were completely established at Alexandra in Central Otago, so that it was possible to distribute weevils to Timaru and Little River.

By May 1934 the weevils were so well established at the Cawthron Institute and on the adjoining hills to which they had spread, that general distribution throughout the Dominion commenced; this was continued until 1947, by which time 200,000 had been sent to 340 localities (Miller, 1947) and distributions had been made by farmers themselves.

Establishment is now country-wide; the insect has spread freely, mountain ranges being no barrier. Probably it infests gorse at the highest altitudes at which the weed survives; Mr. J. Acland (pers. comm.) reported in 1941 that, at an altitude of 3,500 ft at Peel Forest in Canterbury, there was hardly a bush in a large area of gorse on which the weevil could not be found, and that it had noticeably influenced seed production.

The highest pod infestation so far recorded is 98.67% at Alexandra, with all seeds destroyed, and 80%, with complete destruction of seed, is common enough in the Waimea County; but no comprehensive survey has yet been made. Recent records by Moss (1960) reveal that from 20% to 40% of the summer seeds were destroyed by the insect in areas near Wanganui, and 41% in the Manawatu. During the spring and summer of 1939, the percentage of pod infestation at the Cawthron Institute was 17% in September, 26% in October, 64% in November and 76% in December; while during January 1943, at 10 different localities in the Waimea County, the range of infestation was 10.6%, 24.8%, 46%, 47%, 77%, 77.5%, 78.4%, 82.5%, 88%, and 95%, with complete destruction of the seeds. In other districts during January 1943, the percentages were 86 at Fairlie, 61.5 at Makikihi, 43 at Ashburton, 40 at Karama (in the South Island), and 18.5 at Puketitiri, Hawke's Bay (North Island). Although the position appears to vary according to season and locality, little can be concluded from the available data except that the weevils can exercise a varying degree of control; that this can be high at times is indicated by the experience a few years ago of a Nelson farmer who grew gorse as fodder for his sheep but was unable to secure seed even when he offered 4s. per pound.

Cycle in New Zealand. No proper field study of the bionomics of *A. ulicis* in New Zealand has been undertaken; the only records available are of sporadic yearly observations made from the time of liberation in 1931 until the close of 1940, and the following account has been constructed therefrom.

Weevils occur on gorse throughout the year; though usually dormant during winter, there is no true hibernation, the insects responding to favourable winter conditions (as does the gorse), and even reproducing in that season. As was found with some consignments of imported weevils, an autumn generation is produced, corresponding to that found in the spring in south-west Gascony by Perris (1876); it would seem that this could occur in England, though not yet recorded. As far as is known, the major reproductive activities take place from early spring until late summer when suitable pods are available; pods of the autumn flowering dehiscence in late autumn (perhaps also in winter), and in spring (August and September) releasing the autumn and any winter generations of weevils; pods from the spring and summer flowering dehiscence from October until the following February and March, during which period the spring and summer generations are released.

PIRIPIRI

Acaena anserinifolia (J. R. et G. Forst.) Druce

INTRODUCTION

This weed is native to New Zealand and belongs to the rose family. It is commonly known by its Maori names, piripiri and hutiwai, and by the European variant, bidibidi. These names tend to be applied indiscriminately to several related species, all characterised by globular burrs bearing barbed spines, which attach themselves to, and mat, the wool of sheep to such an extent as to reduce seriously the market value of the clip. Because of this, research into the possible biological control of the weed was undertaken.

The worldwide distribution of *Acaena* has been described by Dawson (1960, p.13): "Estimates of the number of species in the genus have varied from a few dozen to over a hundred. The actual number is probably somewhere between these extremes. Of these only a handful are found in the northern hemisphere—1 in California, 1 in Mexico and 1 in Hawaii, as well as a few others which extend across the equator in South America. In the southern hemisphere the majority of species (perhaps 50) are found in South America. The remaining 17 or so are distributed as follows: New Zealand, 14 (1 of these extends to Australia); Australia and Tasmania, 3; South Africa, 1; and 1 or 2 in the isolated islands of Tristan da Cunha, Kerguelen and Macquarie."

For the New Zealand Botanical Region (including Macquarie Id) Allan (1961) accepts 15 species, all occurring in the South Island except the 2 which are confined to the Subantarctic Islands; 5 are recorded also in the North Island. *A. anserinifolia*, in one or other of its many forms, is known not only from both the main islands but also from Stewart and Chatham Islands.

INSECTS OF PIRIPIRI

NEW ZEALAND

Acaena is in general not damaged by insects in the Dominion, except, perhaps, for a species of root-feeding mealy bug, which exists in considerable populations especially in places where the weed has seemingly died out; this mealy bug was identified as *Pseudococcus araeae* (Mask.), a species found on the roots of many other plants. Omnivorous species of tortricid and noctuid caterpillars, a species of white fly, a species of leaf hopper and a species of aphid feed on piripiri foliage, but are not harmful to the weed under natural conditions.

AUSTRALIA

The Australian blue flea-beetle, *Haltica pagana* Black., plays havoc with *Acaena* foliage, but it also attacks strawberries (Tillyard, correspondence).

CHILE

Owing to the range of *Acaena* species in South America, it was decided to investigate the position there. On the advice of the late Dr L. O. Howard, of Washington, D.C., we communicated with Brother Claude Joseph, of the Instituto San José at Temuco in Chile, who agreed to undertake studies in that country. He soon discovered the sawfly, *Antholcus varinervis* (Spin.), the larvae of which caused much damage to the foliage and developing flowers of the weed, and was not known to attack any other plant; also, an important feature of the insect was that it aestivated as prepupae, and that the imagines were active in late autumn and during the winter when few rosaceous crops were in foliage at the time of oviposition and larval activity. It was also found in Chile that the larvae of a flea-beetle, *Haltica virescens* Blanch., attacked *Acaena* foliage, and a consignment of eggs was brought by ship's vegetable chamber to New Zealand; but though larvae hatched from the eggs, nothing came of them. By that time it had been found that the insect was not restricted to *Acaena*, and *A. varinervis* was selected for study in New Zealand.

After Brother Joseph had studied the life history of the sawfly in Chile (Joseph, 1928 and 1929), and had made some experimental shipments of eggs, larvae and prepupae to New Zealand, the writer visited Chile in 1930, and again in 1935 in order to re-establish the work which had become disorganised after Brother Joseph had returned to France; the visits were financed by the Cawthron Institute Trust Board, the New Zealand Meat Producers' Board, and groups of interested farmers in the North Island.

The consignments, except for the first four which came by post, and part of one carried by the writer under different methods of packing at ordinary temperatures, travelled in ships' vegetable chambers (38 deg. F to 40 deg. F); they were transhipped to a New Zealand steamer at Panama Canal where arrangements had been made for the material to be held in cool store when there was any delay.

ANTHOLCUS VARINERVIS (Spin.)

METHODS OF SHIPPING

In sending supplies of *A. varinervis* to New Zealand, best results were obtained when prepupae were packed in tin boxes of sterilised soil and carried in the vegetable chambers of ships. Prepupae packed in soil travelled quite well at ordinary temperatures when brought personally by the writer; in these circumstances the temperatures were not excessive for any length of time.

At first, consignments were prepared as follows: In tin boxes measuring $10 \times 6 \times 2\frac{1}{2}$ in. sterilised soil (slightly moistened with distilled water) was placed and firmly compacted; with a $\frac{3}{16}$ in. glass rod rounded at the end, numerous holes were made in the soil to a depth of 1 in., and into each of those was placed (head upwards) a prepupa exhumed in the field and removed from its earthen cocoon; sometimes two such layers were prepared in one box, each covered by a sheet of filter paper.

As this method involved a great amount of labour, both in the field and in packing, the number of insects that could be shipped during a season was limited; so the technique was modified in 1935. Large numbers of maturing larvae were collected in the field and fed on *Acaena* foliage placed in a wire-netting frame over several tin boxes of sterilised soil on to which the maturing larvae would drop, bury themselves, and transform to prepupae. The accumulated frass, which encouraged fungus growth, was frequently removed from the surface of the soil. When the number of prepupae was thought to be sufficient the boxes of soil were removed, replaced with others, and fitted with a sealed lid ready for shipment. There were certain drawbacks to this technique: only a very rough estimate of the number of prepupae in a box could be made, and the larvae tended to congregate and burrow at the corners of the containers, so creating more favourable conditions for fungus growth amongst congested prepupae. Congestion of prepupae resulted, at times, in a considerable mortality during transit, but that was checked on arrival by unpacking the infested material, removing the prepupae from the soil, and placing them in petri dishes, where they developed satisfactorily.

REARING METHODS

Since *A. varinervis* is a southern-hemisphere insect, it was not involved in a seasonal synchronisation in New Zealand. It was easily reared, and a colony was readily established in an insectary, where it maintained itself over the years. So prolific was the insect at times that the dense growth of *Acaena* covering the floor of the insectary was completely eaten out, and supplementary supplies had to be gathered from the field. Attention was required, however, to prevent epidemics of a *Cordyceps*-like fungus that was likely to attack the prepupae and pupae when populations became congested; at such times the insects were exhumed and the healthy ones placed in petri dishes as soon as the fungus appeared above ground.

The insectary in which the colony was maintained measured $11 \times 11 \times 6$ ft. The walls and ceiling were covered with a fine mesh gauze, and the ridged roof was asymmetrical, having the longer side of glass facing north and the shorter, covered with rubberoid, facing south and pierced with apertures for ventilation; an entrance baffle porch was attached to the south wall.

To obtain sawflies emerging from imported material, the prepupae were either removed from the soil in which they had been transported

and placed on filter paper in petri dishes where they pupated and produced adults, or they were left undisturbed and the tin containers embedded in soil beneath an emergence frame in a glasshouse (Fig. 14); this frame consisted of a steeply sloping glass front fitted with doors, and a top of book muslin sloping downwards from the glass front toward the back. As it was difficult to keep trace of all the sawflies emerging within the frame, Messrs Fraser and Kelsey designed and made an excellent trap (Fig. 15) described by Kelsey (1945).

The sawfly was very easily reared, and for life-cycle studies special breeding cages were used. These consisted of three parts:

- (1) A cage made of a wooden frame measuring 21 in. long, 18 in. high, and 10 in. wide; the two long sides were glazed, the two ends and the top covered with fine-meshed gauze, and the bottom left open, while at one end the lower part of the gauze was replaced by a small door for access.

- (2) A wooden trough standing on short legs and measuring 21 in. long, 12 in. high, and 10 in. wide; this was lined with zinc having a half inch hole in the bottom for drainage.

- (3) A board 18 in. long and 10 in. wide.

The trough could be filled with soil on which *Acaena* was grown, the cage stood over and hooked to it, and the sawflies were released therein; by this means the resultant larvae could enter the soil for their transformations. A drawback was that no check could be kept on the progress of the insects when underground, so that they had to be exhumed and kept for observation in petri dishes: there was also a danger from fungus invasion, and it was difficult to keep soil moisture favourable for the insect, excess moisture being very unfavourable. On the other hand, the cage could be fixed over the board on which were stood vessels of water containing *Acaena*; by this means the larvae could be collected and transferred to petri dishes, and their transformation to adults readily observed.

When the time came for field liberations, the adults and larvae secured from the insectary, together with the sawflies from consignments, were used for distribution. Measures had to be taken frequently in the insectaries and breeding cages to control not only slugs and caterpillars, which devoured the *Acaena* leaves and *Antholcus* eggs, but also spiders, which snared the adult insects.

CONSIGNMENTS

Over a period of 12 years (from 1928 to 1940) 17 consignments were received from Chile; owing to temporary disorganisation in Chile there were breaks in the sequence of supplies in 1933, and again in 1938 and 1939. Except for the eggs and larvae in the first experimental shipment, all contained prepupae; the first four consignments came by post, and the remainder in the ships' vegetable chambers except for some carried at ordinary temperatures by the writer on two occasions.

There was usually a very high mortality during transit, partly natural and partly due to the confined conditions in the containers, especially when fungi developed. The number of insects in each consignment (1 to 10) was known until the winter of 1935, when the technique was developed for securing large numbers of prepupae for shipment; consequently only a very rough estimate of the contents of consignments 11 to 17 could be given. The consignments are listed in Table 6.

TABLE 6. *A. varinervis*.

Consignment	Contents	Date Received	Emergences			Parasites
			Males	Females	% Males	
1	Eggs and 50	28 Aug 1928	0	0	—	0
2	larvae 51	4 Oct 1928	0	0	—	0
3	100	7 Nov 1928	0	0	—	0
4	98	10 Apr 1930	0	0	—	0
5	1,200	28 Oct 1930	2	194	1.02	0
6	23	24 Sep 1931	0	3	—	0
7	1,935	5 Mar 1932	5	162	2.99	0
8	250	2 Jun 1934	0	9	—	4
9	48	9 Apr 1935	0	6	—	0
10	80	8 May 1935	0	0	—	0
11 } 12 }	9,400	{ 16 Jan 1936 } { 10 Mar 1936 }	486	6,071	7.41	40
13	1,002	2 Mar 1937	4	607	0.65	68
14	5,010	29 Apr 1937	45	1,616	2.70	25
15	3,200	12 Mar 1940	71	1,979	3.46	24
16	600	17 Apr 1940	10	366	2.65	3
17	3,410	22 May 1940	38	679	5.29	20
Totals	26,407 (prepupae)		661	11,692	5.35%	184

When considering the data in the above table, the 2nd, 3rd and 4th consignments can be excluded since they had been sent through the post. From the remainder, sent as prepupae in soil, 26,158 reached New Zealand and gave rise to 12,353 sawflies (or 47.22%); this was quite a satisfactory result from this method, and the numbers would have been higher but for a fungus that sometimes destroyed considerable numbers before it was controlled. The small proportion of males and the dominance of the females are characteristic of the species. There was very scant parasitism by a braconid, more than one of which sometimes emerged from a single host.

BIONOMICS

CHILE

Brother Joseph (1929) studied the bionomics of *A. varinervis* in Chile during 1928. According to his observations, the insect aestivates as prepupae in chambers in the soil, and though water and the rootlets

of vegetation penetrate those chambers, no appreciable damage to the prepupae results. During April pupation takes place, the pupal state lasting for about 20 days. Adults start to emerge from the ground in the first week in May and continue to do so throughout that month; at that time the soil is moist, so a passage is easily opened by the emerging sawflies, and the number that have emerged can be calculated by the number of emergence holes. Emergence occurs in the morning and takes two to three hours.

The sawfly is 6–8 mm long (Fig. 16); the head, antennae, thorax, last abdominal segment and parts adjoining the ovipositor are black, and the rest of the abdomen and the feet are yellow. Males and females fly over *Acaena* plants where they mate; the male dies a few days later, but the female lives from two to three weeks longer; both are active during the hottest hours of the day, especially in sunlight. A few days after copulation the female becomes less active on the wing, though it will fly for considerable distances during sunny days, and as its abdomen becomes distended it moves over, and explores, the surface of the *Acaena* leaves. Oviposition commences about two weeks after copulation; the ovipositor forms a pocket under the leaf epidermis in which the eggs are placed bathed in a viscous secretion. The act of oviposition takes about five minutes, after which the insect immediately searches for another spot to continue egg-laying, often in the same leaf so that the egg pockets are both contiguous and scattered (Fig. 17). Joseph observed eggs being deposited by one female at the rate of five to 10 per hour. The insect lies dormant among the foliage during the night, commences to oviposit in the morning, and continues until nightfall. The female takes about two weeks to deposit her eggs, and Joseph counted from 200 to 300 in the abdomen of several insects that had not commenced to oviposit. In the last week of May the females under observation had died without laying all their eggs.

As the eggs gradually increase in size they produce slight swellings on the upper leaf surface and larger ones on the lower; these are readily seen by the end of June. During July, the eggs, still increasing in size, sometimes break through the lower leaf epidermis exposing one pole, which is of a greenish-violet colour. The larvae hatch in mid June and appear in increasing numbers on subsequent days; in shady situations hatching continues into August and September. The young larvae attack the lower leaf surface; growth is slow at first, but after a week or so the larvulae migrate to the tender young leaves where they grow rapidly and cause more damage to the plant (Fig. 18). Both eggs and larvae resist cold and rain; the larvae prefer direct sunlight, but when it is very hot they shelter among the foliage and flowers.

By August and September well developed larvae are abundant on the upper surface of the leaves, attacking the young developing ones so that the growth of the plant is markedly checked. In October and November, the green larvae (now about 2 cm long) cause much damage as they travel from leaf to leaf; they fall to the ground if the plant is even slightly disturbed.

From October or November onwards, the *Acaena* flower stems rise above the foliage, and the larvae climb them to devour the buds and flowers; on very hot days they will lie curled up under the inflorescence and gnaw through the stem until it is decapitated, so preventing the ripening of the flowers.

The mature larvae drop to the ground, where they wander about for several days beneath the *Acaena*. The soil is hard by this time, and with some effort, occupying about a week, they burrow to a depth of from 5 to 10 cm, widen the bottom of the shafts, impregnate the earthen walls with saliva, and construct calcareous-like capsules in which they rest vertically, head upwards, the body being noticeably contracted (Fig. 19). Joseph concluded that the cycle occupied two years because some of the prepupae he exhumed gave rise to adults in April and May of the following year, and others produced sawflies in the year of collecting. The only parasite known in Chile is a braconid attacking the subterranean stages.

NEW ZEALAND

The following data were secured over a period of 7 years (1930 to 1937).

The activities of the insect were found to be sometimes earlier, or later, by as much as a month according to seasonal variations. Generally the first sawfly emerged during the last week of April (virtually as in Chile, but the earliest New Zealand record was in March), the insects increased in numbers through May, June, and July, decreased during August, and ceased emerging in September (on one occasion in October). The average life of the sawflies varied considerably; limited observations gave an average life of 22 days, the range being from four to 48 days, those emerging in September being consistently short lived (four to seven days). The sexes were strikingly disproportionate, the females predominating; in the consignments, the percentage of emerging males ranged from 0 to 7.41, but the proportions may have been influenced by the abnormally high mortality among prepupae during transit. During rearing experiments in New Zealand, where the influences were natural, the percentages of males ranged from 0 to 29.29.

Observations in New Zealand revealed that *A. varinervis* reproduces both sexually and asexually. From the small 8th consignment only nine females emerged, and these during transit; all but four survived. Though malformed they readily oviposited in June, 1934, and the larvae from the few eggs were reared to produce two females in May, 1935. From the much smaller 9th consignment, six normal females emerged in May, 1935, and oviposited in June; 140 larvae reached prepupation and gave rise to 13 females in May 1936. Though reproduction was asexual, it would be unwise to conclude from such meagre material that the progeny of unfertilised females would always be solely of that sex.

On the other hand, interesting results arose during the mass rearings from larger numbers of sawflies of both sexes. In one case, 286 females

were used. They had emerged from a consignment and were collected from traps in which there were no males; but since males and females were also found in other traps over the same consignment it is reasonable to assume that at least some of the females trapped alone could have been fertilised before entering the traps. From these females a generation of 191 males and 461 females was secured. In a second case, 4,410 females and 320 males, among which pairing had been observed, were used for rearing. A very large population of larvae resulted. To secure some indication of the sexes that would develop 1,263 mature larvae were collected and were reared separately; these produced 19 males and 809 females. In both these cases, however, there could have been a proportion of unfertilised parent females, as would occur under natural conditions.

Joseph (1929) considered the insect's cycle was biennial. Therefore, though sawflies emerged from some consignments in both the first and second years after arrival in New Zealand, it was assumed that all those emerging in the first year were from prepupae that had developed the year prior to, and the others during, the years when collected. However, New Zealand studies revealed that the cycle can be both annual and biennial, so that some of the sawflies emerging in the first year could have been of an annual generation.

Oviposition took place soon (very often immediately in the case of unfertilised females) after the sawflies emerged. From one to four eggs were found in egg pockets. The number of eggs laid by individual females ranged from 36 to 75; the female that laid the 75 eggs was dissected after death and contained 50 eggs in various stages of development. Other females that had died before completing oviposition contained from 30 to 50 apparently mature eggs, and sometimes as many as 60 immature ones; dissections before oviposition revealed up to 120 developing eggs in the ovaries. Observations on incubation showed an average of 52 days, with a minimum of 23 and a maximum of 74; in May the incubation period was 30 days, and in June 23 days.

The larval period was generally from May to December (inclusive), and lasted 60 to 91 days, with an approximate average of 76 days. The larvae, which were most numerous during June, July, and August, not only favoured the young *Acaena* leaves, but, when abundant, also completely defoliated the plant; they also attacked the flowers as soon as these appeared in September and October. During times of high larval population, it was thought that the feeding larvae might destroy the egg pockets, but no sign of this was observed; it is possible that because the leaf epidermis enclosing the egg pockets dries up, the food is unpalatable to the larvae.

The mature larvae generally began to enter the ground for prepupation during August, and continued to do so until the close of December. The prepupal period averaged 255 days, extremes being 125 and 325 days in the case of an annual brood, but passing another year when biennial. However, there were indications that some of the prepupae pupated in the first year, and passed into the second year as pupae before sawflies emerged. In an annual brood the pupal period averaged

29 days with extremes of 14 and 30, and the cycle from egg to adult occupied 380 days in the 1931–1932 season, 340 days in 1934–1935, and 368 days in 1935–36. The above statement on the life history can be taken only as a generalisation, because no critical study of the insect's development was attempted.

PREFERENCE AND STARVATION TESTS

An important feature of *A. varinervis*, relating to the possible extension of its host range to rosaceous plants of economic value, is that the sawflies are on the wing when there are few such plants in leaf; and also that there would be little opportunity for, or likelihood of, the larvae, active in the spring, to migrate from *Acaena* to such plants. Indeed, the seasonal habits of the sawflies and larvae mainly preclude attack on other rosaceous plants even if the insect could do so and survive.

In Chile, neither Joseph (1929) nor the writer in 1930 and 1935 found the insect on any plant other than *Acaena*, not even on the wild strawberry (*Fragaria chiloensis* L.), which is common from the Pacific Coast to the Andes. Experimenting with wild strawberry, Joseph found that the larvae moved over the foliage for a week without eating; after a fortnight some of the young larvae nibbled the lower leaf surface, but they had become very feeble, while those of the same age on *Acaena* were vigorous; most of those on the strawberry died in a month.

Experiments in New Zealand showed that the sawflies did not oviposit in the foliage of blackberry, raspberry, strawberry, roses, or the native bush-lawyer (*Rubus australis* Forst.). On the other hand, in one series of experiments, the larvae in different stages of growth attacked strawberry leaves in the absence of *Acaena*, but immediately returned to the latter when foliage was made available; furthermore, when the larvae were held on strawberry they could not complete their development. Foliage of raspberry, blackberry, roses, and bush-lawyer were not attacked.

LIBERATION AND ESTABLISHMENT

Liberation. Field liberations were first made in June 1936, when 440 sawflies (males and females) were liberated at Pueroa, near Wanganui; in that month and in July further liberations of over 6,000 insects were made in the Hunterville and Wanganui districts, and at Mangimangi, near Eltham. During those months in 1937 liberations were continued in the same places, and further westward in Taranaki to the west coast. Liberations were continued into 1948 in districts including Ruatoria and Putahi in Poverty Bay, Mackay's Bluff, Aniseed Valley and Maitai Valley in Nelson, Kekerengu in Marlborough, and at Alexandra and Otago Peninsula in Otago, while many were retained to maintain a colony at the Cawthron Institute. Altogether a total of 30,000 insects had been liberated from imported and reared material.

Establishment. It was not possible to follow up in detail the establishment of *A. varinervis* after its liberation, but reliable observations were made in one or two areas. After the initial liberations in the North Island in 1936, the insect established in at least two areas where it was active each year into 1940, after which the observations were discontinued. Closer and more regular attention was given to the area on Mackay's Bluff at Nelson, where the insect was well established for four years and had a conspicuous effect upon the weed each season; after 1942, however, the area was burnt over. On the other hand, the central colony maintained at the Cawthron Institute remained so vigorous for many years (until 1956) that often the *Acaena* was eaten to the ground, and the weed had to be brought in from the field to maintain the larvae.

A feature favourable to the establishment of *A. varinervis* in New Zealand was that the family Tenthredinidae, to which it belongs, was not known among the native insects, so could not be interfered with by native parasites of that group. However, there are three exotic tenthredinids established in New Zealand—*Priophorus tener* (Zadd.), *Caliora limacina* (Retz.) and *Pontania proxima* (Lep.); the larvae of the first two are leaf feeders on raspberry and plum respectively, and those of the third live in galls on the leaves of willow. If parasites should ever be established against the first two pests in particular, they might attack the larvae of *A. varinervis*, which opens up a rather interesting point in the use of phytophagous insects. It is quite possible that birds reduced the larval population of the sawfly, as did slugs, leaf-eating caterpillars, and spiders—but the same would be so in Chile.

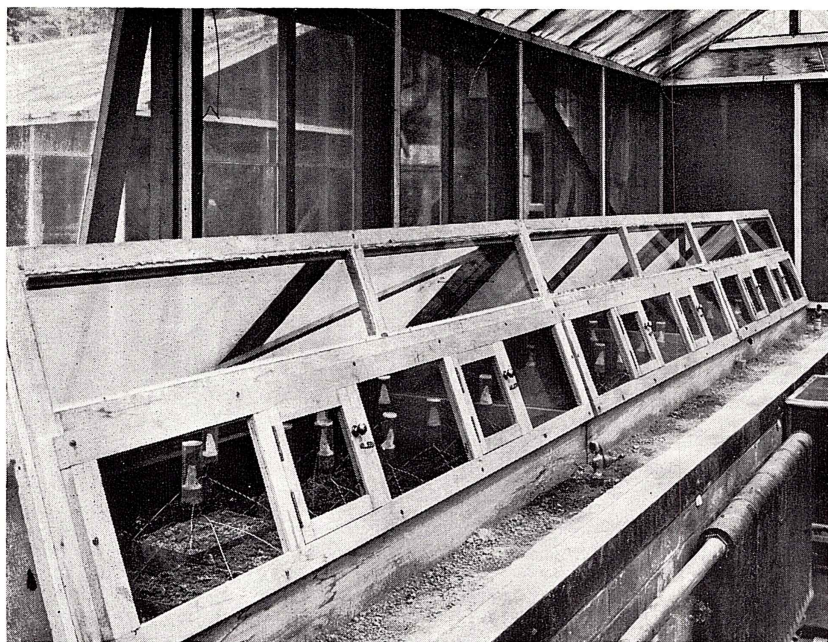


FIG. 14. Structure enclosing "Kelsey" traps for emergence of *Antholcus varinervis*. (W. C. Davies photo.)

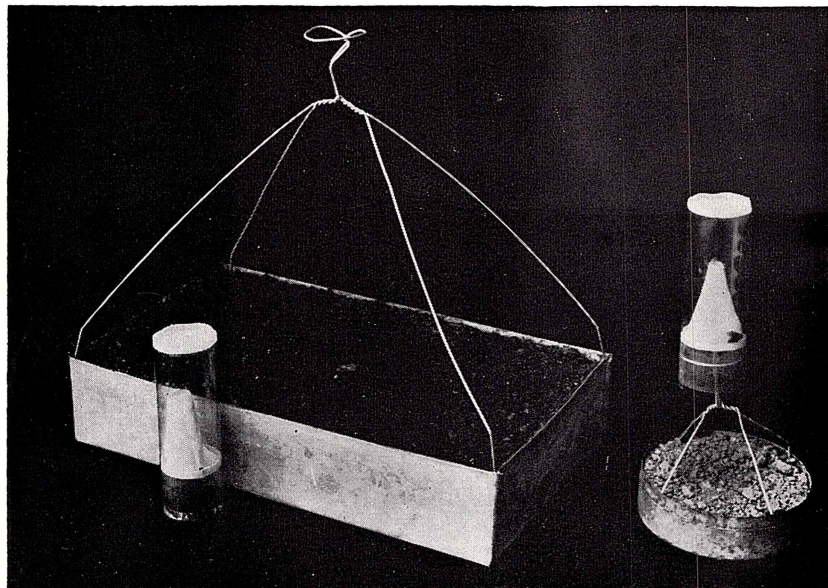


FIG. 15. Details of "Kelsey" trap for emerging *Antholcus varinervis*. (W. C. Davies photo.)

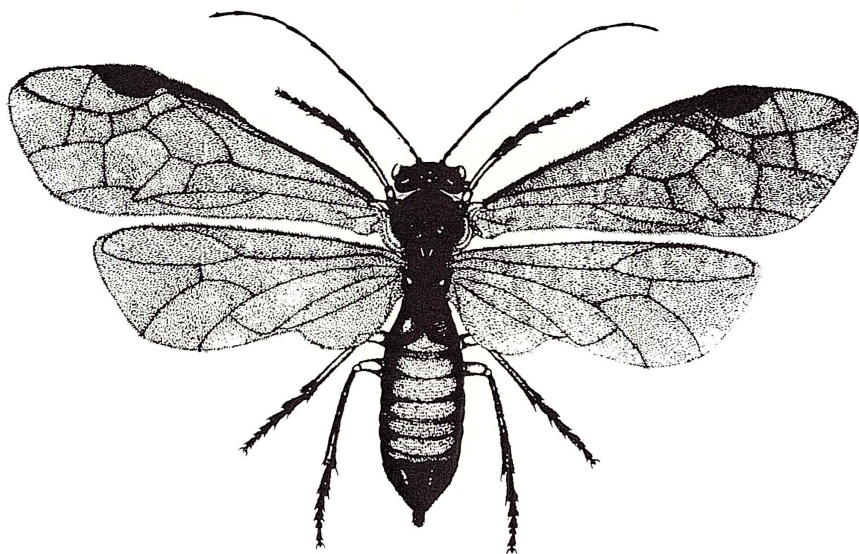


FIG. 16. *Antholcus varinervis*; length 6–8 mm. (J. M. Kelsey del.)

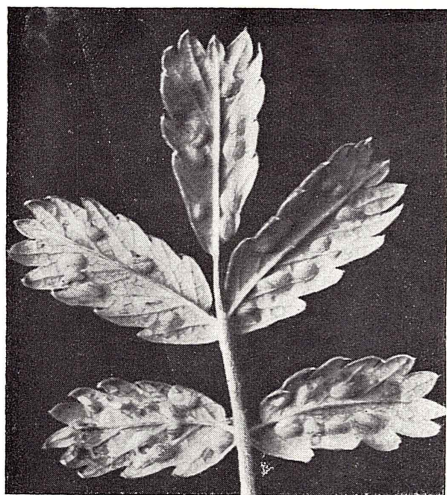


FIG. 17. Egg pockets of *Antholcus varinervis* in *Acaena* leaves. (W. C. Davies photo.)

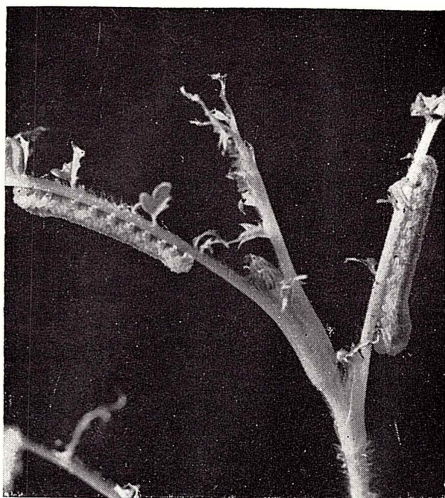


FIG. 18. Larvae of *Antholcus varinervis* attacking *Acaena*. (W. C. Davies photo.)

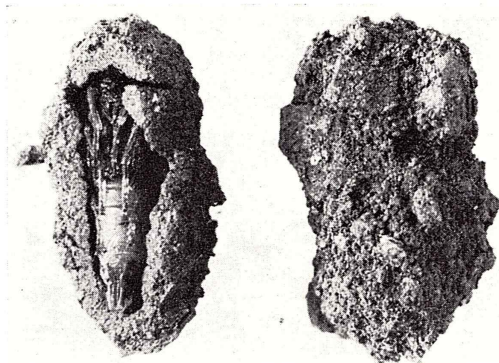


FIG. 19. *Antholcus varinervis* pupae in earthen cells.
(W. C. Davies photo.)

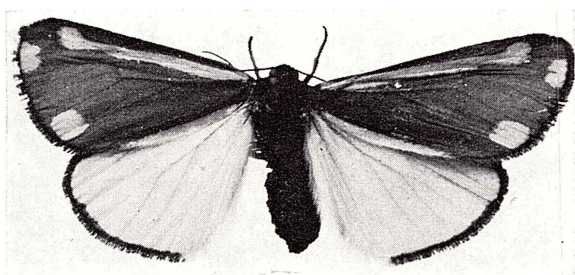


FIG. 20. (a) *Tyria jacobaeae*; length 11 mm. (W. C. Davies photo.)

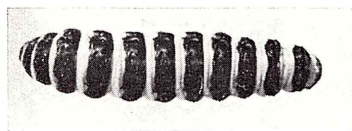


FIG. 20. (b) *Tyria jacobaeae*; larva.
(W. C. Davies photo.)

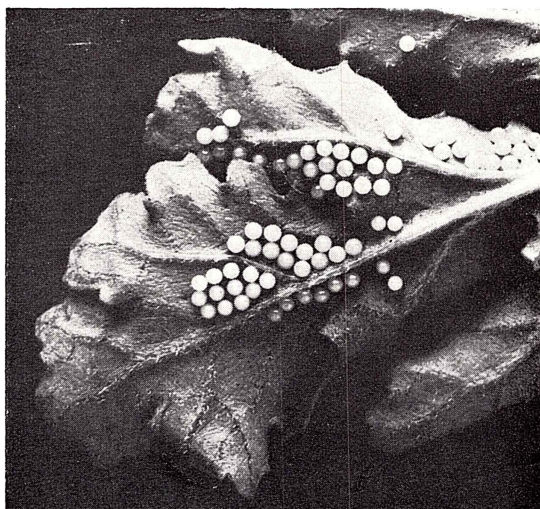


FIG. 20. (c) *Tyria jacobaeae*; eggs on
ragwort leaves. (W. C. Davies photo.)

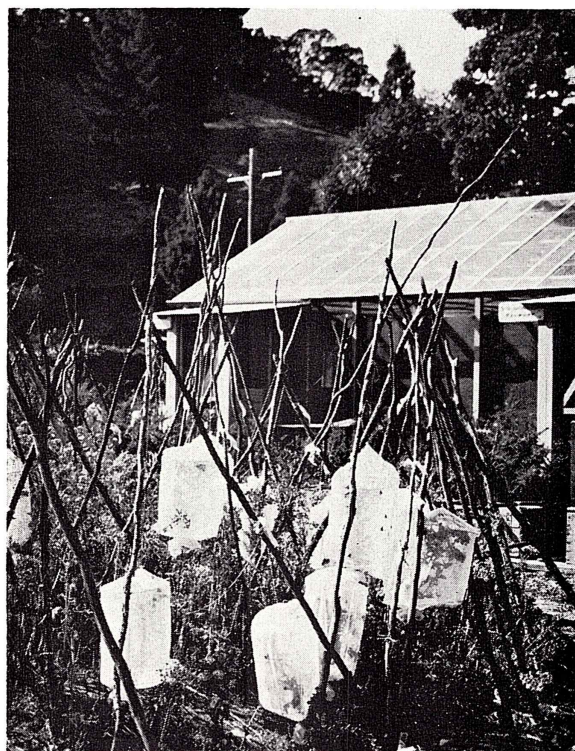


FIG. 21. Muslin cages for oviposition by *Tyria jacobaeae*.
(W. C. Davies photo.)

RAGWORT

Senecio jacobaea L.

INTRODUCTION

The influence of ragwort upon the grazing industry of New Zealand is two-fold: it invades valuable pasture, and the alkaloids it contains are harmful to livestock, especially cattle and horses, which develop hepatic cirrhosis from eating the weed. Furthermore, ragwort flavour in honey has been responsible for many tons of honey being rejected annually.

Ragwort was first recorded in New Zealand from near Dunedin in 1874 (Thomson, 1922), but it soon appeared over considerable tracts in both islands. Poole and Cairns (1940) showed that the main regions occupied by the weed are the most southern counties of Otago and most of the North Island northwards of a line from the Taranaki Bight to the Bay of Plenty; but it also occurs in many localities in other parts of the North Island, as well as in regions of higher rainfall in the South Island to the north of Dunedin, and from Golden Bay southward throughout Westland.

Though the weed has been controlled in recent years by chemical means and by sheep grazing, it is still prolific on abandoned land and inaccessible areas. Flowering generally commences during October, reaches a maximum in December, and continues throughout the summer, falling away during autumn and ceasing as late as April. However, the flowering period varies somewhat with location and seasonal vagaries, and is almost continuous in some places: many plants were in full bloom in March 1941 continuing till April at Ngongotaha, and during winter at Putaruru, and odd plants were also flowering in winter at Nelson.

RAGWORT INSECTS

NEW ZEALAND

The weed is frequented by several species of insects in New Zealand, but the following six, none of which is native to the country, are the only noteworthy ones.

Lepidoptera	<i>Ariathisa comma</i> (Walk.)	Cutworm
	<i>Homoeosoma vagella</i> Zell.	Stem borer
	<i>Nyctemera annulata</i> Bd.	Defoliator
Diptera	<i>Agromyza aeneiventris</i> Flin.	Stem borer
	<i>Phytomyza atricornis</i> Mg.	Leaf miner
Hemiptera	<i>Brachycaudus helichrysi</i> (Kltb.)	Bunches flowers

Of these insects, *Nyctemera annulata*, one of the most abundant and best known species in the country, is the only one that does any marked damage to ragwort. Occasionally the larvae become epidemic and devour considerable areas of ragwort; but the weed readily recovers, and as the damage is infrequent the insect is not an effective controlling agent, though it could be helpful in conjunction with other more potent species if such were found. In addition to ragwort the normal food plants of *N. annulata* are the native species of *Senecio* and *Brachyglottis*, together with groundsel and cineraria. It is attacked by three parasites; the ichneumon *Echthromorpha intricatoria* (Fabr.), which oviposits in the pupae, and two tachinids, *Cerosomya nyctemeriana* (Huds.) and *C. casta* (Hutt.), which infest the larvae. With the exception of *C. nyctemeriana*, these parasites had an important influence on the effective establishment in New Zealand of the cinnabar moth, *Tyria jacobaeae*, one of the insects introduced against ragwort.

The larvae of *Homoeosoma vagella* often infest a very high percentage of ragwort plants over considerable areas. Frequently several larvae inhabit the one stem; they burrow downward through the pith to the crown of the plant; yet the weed survives, flowers, and seeds (Cottier, 1931). The insect is attacked by two unidentified species of Hymenoptera.

The leaf miner *Phytomyza atricornis* occasionally exercises some temporary check by markedly damaging the leaves, particularly advanced ones, over extensive areas: it became quite a problem during research on other insects in the insectaries (Kelsy, 1937). It is parasitised by *Dacnusa areolaris* (Nees). The stem borer *Agromyza aeneiventris* is common but has no marked influence on the weed. The same applies to the aphid *Brachycaudus helichrysi* which occurs as colonies on the flowers bunched together in honey-dewed masses; according to Cottier (1953) this aphid has a wide range of host plants. The omnivorous cut worm caterpillar *Ariathisa comma* damages, and even checks, juvenile ragwort, but it is a pest of economic plants; it is attacked by the tachinid *Cerosomyia marginata* (Hutt.).

BRITAIN AND EUROPE

In Great Britain and Europe numerous insects have been recorded from ragwort, but many of them have a wider host range; Cameron (1935) and Newton (1933) recorded at least 65 species including those in the following list, which offered the more promising possibilities for our purpose.

Lepidoptera	<i>Eucosma nigromaculana</i> Hw.	Attacks seeds
	<i>Eucosma trigeminana</i> Steph.	Stem borer
	<i>Eupithecia oblongata</i> Thumb.	Attacks seeds
	<i>Euxanthia aeneana</i> Hub.	Stem and root borer
	<i>Homoeosoma cretaceella</i> Ross	Attacks capitula and stems
	<i>Phalonia atricapitana</i> Steph.	Attacks capitula and stems
	<i>Tyria jacobaeae</i> L.	Defoliator
Coleoptera	<i>Longitarsus jacobaeae</i> Wat.	Attacks roots and leaves

Diptera	<i>Hylemyia jacobaeae</i> (Hardy)	Attacks seeds
	<i>Hylemyia seneciella</i> (Meade)	Attacks seeds
	<i>Stictodiplosis jacobaeae</i> Lw.	Attacks flowers and seeds

On the advice of Professor Heslop-Harrison, *Tyria jacobaeae* and *Hylemyia seneciella* were selected for study; both are always abundant on ragwort, and only *T. jacobaeae* is found on any other plant (namely groundsel (*Senecio vulgaris* L.)).

TYRIA JACOBAEAE L.

This insect, popularly known as the cinnabar moth, occurs in Great Britain, Ireland and Europe whence it extends into west Central Asia. The moth and its larvae are conspicuously coloured. The former (Fig. 20a) has a black body, and the fore wings are blackish with a subcostal crimson stripe extending from the articulation towards the tip, while there are two spots of the same colour on the outer margin; the hind wings are crimson. The larvae (Fig. 20b) are alternately ringed with black and yellow in the third, fourth, and fifth instars.

BIONOMICS

ENGLAND

The moth is on the wing in the summer during May and June (slightly earlier or later according to seasonal variations). The eggs are laid in clusters on the underside of ragwort leaves (Fig. 20c); according to Cameron (1935) the average number produced per female is 200, and the incubation period is 13 days. The larvae, which are active during May until July and sometimes August, feed preferably on the tips of the plants, but when numerous they clear considerable areas of the weed by eating the flowers, buds, and foliage; Cameron gave one month as the duration of the larval period. The larvae pupate on the ground, using any convenient shelter, and sometimes construct an imperfect silken cocoon. Hibernation is as pupae, and there is a single generation each year. Cameron gave a list of the recorded parasites.

NEW ZEALAND

The following account is based on laboratory observations and on field observations after liberation. The insect is single brooded as in England; it is influenced by regional and seasonal vagaries, the first moth, for example, having been recorded in Southland some six weeks later than in the North Island and Nelson. In general the position is as follows except for Southland.

The first moths have been observed as early as August, at the beginning of spring, so their appearance is seasonally about three months earlier in New Zealand than in England where they are first noted at the beginning of summer. They become abundant in September and October, increasing to a maximum during November, December and January, after which their numbers decrease into March, only a few being seen in April.

Averages recorded at different times of the number of eggs laid per female are 90, 114, 122, and 150; up to 265 have been recorded from one individual. Many eggs are infertile, and there is also a considerable natural mortality among the hatching larvae especially early in the season during sudden fluctuations of temperature. The incubation periods recorded were, 18 days in October, 7 to 8 days during December, January, and February, and 28 days in March and April.

Larvae appear in September, are very numerous by December, and so continue through January and February to decrease in March. During December, January, and February the larval period lasts 26 to 34 days, the duration of the first to fourth instars being four to six days each, and the fifth about 10 days. At the height of their abundance during summer and early autumn, the larvae play havoc with ragwort, temporarily checking it in the same way as when it is mown down; but the weed recovers and grows vigorously.

The larvae are attacked by *Cerosomyia casta*, as much as 53.19% to 78.12% parasitism having been found; as many as three tachinids emerge from one larva. The native shining cuckoo (*Lamprococcyx lucidus* Gmelin) and the common house sparrow (*Passer domesticus* L.) devour the moths, and the cuckoo and possibly the starling (*Sturnus vulgaris* L.) prey upon the larvae.

The mature larvae tend to wander before pupating and are sometimes decimated by a wilt disease when in dense populations. Pupation commences about October, reaches a maximum in the summer, and decreases into the following April. The duration of the pupal period is variable according to whether the pupae develop from spring or summer larvae. In many pupae formed late in the autumn histolysis was incomplete, and the pupae desiccated. A moderate percentage of newly formed pupae are attacked by *Echthromorpha intricatoria*; the cuticle of the older pupae seems to resist the ovipositor of that ichneumon.

CONSIGNMENTS

From 1926 to 1931, 23 consignments were received from England, and had been collected from August to January (i.e. during autumn and winter); all were of pupae except for two experimental ones of eggs. Of the 25,200 pupae in the 5th-9th consignments, 1,100 were sent to Australia, so the record of moth emergence was concerned with the remaining 24,100; no data are now available on the emergence from these consignments individually (Table 7).

SHIPPING AND REARING METHODS

Different methods of packing the pupae for shipment were tried. They were sent among (a) coconut fibre, or (b) damp sphagnum moss in glass-topped tins, or (c) between layers of fine sand separated by altern-

TABLE 7. *Tyria jacobaeae*.

Consign- ment	Date Received	Number Consigned	Moths		Parasites
			Emerged	%	Emerged
		PUPAE			
1	14 Dec 1926	900	196	21.77	510
2	30 Dec 1927	901	216	25.08	0
3 }	(Eggs; see below)				
4 }					
5					
6					
7	14 Oct 1928	7,500	7,104	29.48	0
8	3 Nov 1928	7,500			
9	15 Dec 1928	7,000			
10	3 Jan 1929	1,100			
11	27 Feb 1929	1,000			
12	24 Oct 1929	19,257	461	2.39	1,270
13	5 Nov 1929	15,100	575	3.80	988
14	12 Nov 1929	20,000	721	3.60	964
15	4 Dec 1929	18,000	754	4.18	537
16	29 Jan 1930	6,700	1,285	19.17	76
17	19 Sep 1930	14,240	4,070	28.58	198
18	4 Oct 1930	28,400	9,742	34.30	401
19	29 Oct 1930	42,000	9,201	21.90	287
20	12 Nov 1930	20,400	9,055	44.38	246
21	6 Jan 1931	1,000	606	60.60	-
22	27 Jan 1931	1,520	818	53.81	-
23	27 Sep 1931	30,400	2,461	8.09	162
	16 Oct 1931	54,840	7,374	13.44	1,252
	12 Dec 1931	33,390	5,357	16.04	428
Totals		331,148	59,996	18.11	7,319
		EGGS			
3	15 Jul 1928	5,000	-		
4	14 Oct 1928	5,000	-		

ate layers of tiffany and damp moss, or (d) with the sand replaced by coconut fibre in tin boxes. None of these methods appeared to have had any particular influence on moth emergence, but as coconut fibre tended to absorb moisture and so encourage desiccation of the pupae its use was abandoned. Also considered was the possibility that pupae collected in the field suffered by being disturbed. However, results of an experiment with pupae that were reared undisturbed in the laboratory rather discounted the possible influence of mechanical interference, though none of the pupae was parasitised.

For the emergence of moths and parasites from the consignments, the pupae were spread on a layer of damp sand in large galvanised iron boxes fitted with wide emergence glass tubes. The parasites were segregated and killed, and the moths were placed in large mating cages and later transferred to ragwort enclosed in muslin cages supported by wire frames (Fig. 21). Twelve pairs of moths were placed in each cage;

after seven days the surviving moths were transferred to new cages, and the leaves, carrying the eggs, to others where the larvae hatched and developed on the ragwort. At times there were as many as 200 such cages being so used in rotation. As the larvae matured they were removed to pupation boxes where the pupae were collected as they developed.

HISTORY OF CONSIGNMENTS

PUPAE

The pupae of all consignments had been collected during the English autumn and winter, and would normally have produced moths in England from May onwards. In spite of the very high percentage of pupae from which moths failed to develop in New Zealand, sufficient numbers of the insects were obtained for research; the only major difficulties in the rearing of progeny from them lay in the devastation caused at times by a wilt disease among crowded populations of larvae and by abnormal low temperatures, which inhibited the hatching of the eggs.

The pupae had been transported at about 40°F either just prior to, or when hibernating, but they produced moths when subjected to the New Zealand spring and summer conditions, just at the commencement of, during, or after their normal wintering period, so the emergences were much earlier than they would normally have been in England. On the other hand, some pupae of two consignments did not produce moths until September in the New Zealand spring, and so were of abnormally long duration. The pupae in one of these consignments had only a brief pre-winter of six weeks in cool store during transit, and persisted through the New Zealand spring, summer, autumn, and winter; in the other the wintering in transit had been at the normal time but shortened to about six weeks so that the pupae passed the summer, autumn, and winter before producing moths. From this it would appear that complete hibernation is not obligatory with most pupae, but is with some.

In the record of moth emergences given in Table 8 the consignments are grouped according to the months when the pupae were subjected to New Zealand spring and summer conditions. The period in transit (six to seven weeks) was in some instances followed by a further period in cool store in New Zealand. All emergences ceased in March, the length of each emergence period depending on the time of removal of the pupae from cool store. That the time of first emergence was not governed by the length of time the pupae were subjected to low temperature, whether out of season or not, is indicated by the records given in Table 9.

As Table 7 shows, the degree of parasitism varied considerably in the different consignments. No indication can be given of the actual number of pupae parasitised because, according to Cameron (1935), more than one parasite, and also several of the one species, can emerge from the one host.

TABLE 8. *Tyria jacobaeae*

Consign- ment	Collected in England	Cool Store		Moth Emergences
		Date Removed	Duration	
5	August	14 October	7 weeks	December to March
10	September	24 October	6 weeks	December to March
21	August	1 October	7 weeks	October to March
22	August	16 October	7 weeks	October to March
11	September	5 November	7 weeks	December to March
12	September	12 November	7 weeks	December to March
15	August	6 November	9 weeks	November to March
16	August	11 November	13 weeks	November to March
17	September	12 November	8 weeks	November to March
1	October	14 December	6 weeks	January to March
2	November	30 December	6 weeks	January to March
6	September	3 December	11 weeks	December to March
7	November	15 December	7 weeks	December to March
13	October	4 December	6 weeks	January to March
18	September	12 December	11 weeks	December to March
23	October	12 December	7 weeks	January to March
8	November	3 January	6 weeks	January to March
14	December	29 January	6 weeks	February to March
19	November	7 January	7 weeks	February to March
20	December	27 January	6 weeks	February to March
9	January	27 February	6 weeks	February to March

TABLE 9. *Tyria jacobaeae*.

Consignment	Collected	Under Low Temperature	Emerged after Removal From Cool Store
<i>Autumn</i>			
5	August	7 weeks	10 weeks
15	August	9 weeks	5 days
16	August	13 weeks	3 days
17	September	8 weeks	2 days
18	September	11 weeks	3 weeks
1	October	6 weeks	4 weeks
<i>Winter</i>			
2	November	6 weeks	2 weeks
8	November	6 weeks	2 days
19	November	7 weeks	7 weeks
20	December	6 weeks	4 weeks
9	January	6 weeks	1 week

EGGS

One of the two consignments of eggs was collected in May (summer) and arrived in New Zealand in winter in apparently good condition after some seven weeks in cool store (40°F) during transit. The eggs were dealt with in six lots. The first lot was submitted on arrival to normal temperatures, being first slightly warmed, and signs of hatching were observed after the sixth day; the larvae were to be seen moving within some of the eggs and endeavouring to eat their way out, but none succeeded, perhaps owing to lack of vitality or to some inhibiting changes in the egg chorion; after a further seven days all the larvae had died and the remainder of the eggs had collapsed. The second, third, fourth and sixth lots were removed nine, 16, 29, and 45 days respectively from cool store after arrival, but there was no sign of development, and all the eggs had collapsed within two or three days. The fifth lot, which had been removed from cool store after 41 days, contained living embryos, but all had perished in two days. The second consignment of eggs had been collected in August (early autumn) and arrived in the New Zealand late spring after about seven weeks in transit in cool store; they were mouldy, in very poor condition, and did not develop.

On one occasion when an excessive number of eggs was secured from New Zealand-reared moths in January, 50,000 of them were placed in cool store (40°F); of those submitted to out-of-door summer conditions only 30% hatched at the end of one month, and hatching decreased proportionately among the others the longer they were held at the low temperature.

TESTS ON PLANTS OF ECONOMIC IMPORTANCE

In addition to the tests carried out in England, starvation, preference, and oviposition tests were undertaken in New Zealand on the following plants: blue lupin, broad beans, cabbage, Cape ivy (*Senecio mikanioides* Otto.), carrot, *Cineraria maritima* L., cocksfoot, field beans, garden cineraria, groundsel (*Senecio vulgaris* L.), hop, lettuce, lucerne, peas, potato, rape, red clover, scarlet-runner beans, *Senecio sylvaticus* L., sunflower, tomato, vetches, and several native species of *Senecio*, viz. *bellidioides* Hook., *compactus* Kirk, *greyi* Hook., *kirkii* Hook., *lagopus* Raoul, *lautus* Willd., *perdicioides* Hook., *remotifolius* Petri.

In starvation and preference tests with larvae in different instars, the only plants attacked were cineraria, groundsel, peas, and potato, the last two, only slightly. The larvae tended to migrate from cineraria and groundsel to ragwort when this plant was made available. The reason for including carrots in the tests was that, in France, Dumont (1928) had reared some pupae and moths from larvae fed on freshly sliced carrots and on roots with broken epidermis.

Because of the nibbling of pea foliage, further tests with 20 varieties were carried out, but apart from a slight nibbling of the Stratagem variety by 5th instar larvae there was no damage, and the insects perished. It had been reported from England (later found erroneously)

that *Tyria* larvae attacked potato foliage, so a comprehensive test on 16 varieties was undertaken. All instars were used; the 1st to the 4th died without damaging the plants, except for a slight attack on the stems of the Golden Coin, Sutton Supreme, and Early Regent varieties, but in two instances the 5th bored into the stem of the Up-to-date variety and pupated. Other larvae, however, pupated without attacking, so further feeding did not seem necessary for pupation; a larva that had eaten a small hole in the stem of the White Hebron variety died without transforming.

Oviposition tests were carried out with *Tyria* moths on garden cineraria, groundsel, potato, peas, and a number of native species of *Senecio*. Eggs were laid in a few instances especially in the presence of ragwort flowers, but the emerging larvae died except on groundsel. From repeated observations it is considered that no weight should be given to these tests, as it was found on many occasions that oviposition took place on any kind of surface (paper, muslin, glass) when the temperature was sufficiently high and the moth pressed by the oviposition urge.

LIBERATION AND ESTABLISHMENT

Liberation. Early in 1929 the permit was secured for the field liberation of *Tyria jacobaeae*. Eggs were obtained by enclosing the moths with growing ragwort in muslin cages, from which the leaves carrying the egg masses were removed and dispatched. Consignments were sent to the district Field Instructors of the Department of Agriculture, who placed the egg-infested leaves in blocks of ragwort where there would be little interference by cutting, burning, and livestock. From 1929 to 1932, approximately 3,400,000 eggs were so distributed on ragwort areas throughout the Dominion, mainly in the Nelson, Auckland, Taranaki, and Southland Provinces, as follows: February to March (1929) 502,000, November (1929) to March (1930) 269,800, November (1930) to March (1931) 1,670,600, and November (1931) to March (1932) 957,300. Minor liberations were made in Westland during 1930.

Establishment. In the out-of-doors ragwort plots at the Cawthron Institute *Tyria* readily established and devastated the weed each year until the plots had to be used for research on the seedfly *Hylemyia seneciella* in 1932. Field surveys were carried out in other parts of the country but were limited by lack of funds.

In December 1929 and December 1930, surveys were made of the areas of liberation in Westland and in the North Island. In Westland (Waimunga Experimental Farm), where liberation had been made early in 1930, the insect was established, but the larvae were not very abundant. In the North Island satisfactory results were found at Waipuku (near Stratford), at the Mamaku State Farm, and at Te Puke. In the areas of Waipuku and Mamaku where the earliest liberations had been made in December 1929 the insect was on the increase in January 1931, the larvae being abundant and their influence upon the weed perceptible. In December 1929, larvae (progeny of hibernating pupae

arising from the eggs first liberated early that year) were abundant at Te Puke and Pirongia, and at the former locality were so numerous that the weed was severely checked, 100 larvae on a single plant being not uncommon; the position was the same at Te Puke a year later (1930), but there was then no sign of them at Pirongia.

During December 1931, Te Puke, Kaharoa, Mamaku, Pirongia, Te Kuiti and Waipuku were visited. At Te Puke, where the larvae had been so abundant a year earlier, very few larvae were to be found, and later reports recorded a near absence of the insect. At Kaharoa, where liberations had been made early in both 1930 and 1931, the larvae were extremely abundant and spreading. They did not seem to have increased to any great extent at Mamaku, but this may have been due to the fact that cattle had been allowed to graze on the experimental area. The position at Pirongia was again disappointing, and at Te Kuiti and surrounding districts the insect had not satisfactorily established; on the other hand, the larvae were again found in large numbers at Waipuku.

In November 1932 the only survey made was at Waipuku, where the larvae had almost disappeared. No further surveys were carried out, but from reports received during the following years it became apparent that the insect had failed to maintain its establishment except in one or two localities. At Arapuni and Horahora, on the Waikato, effective populations of *Tyria* appeared over the years, up to November 1941 at least when the last record was received, and reports revealed that the insect had spread to Pairere, Tirau, and Ngatira. So numerous were the larvae at Arapuni each year that their attack on ragwort was evident, and larvae were readily obtained for distribution to other places, while pupae could be found without difficulty under stones on the ground. Sporadically, into recent years, *Tyria* moths have been received for identification from Masterton, Carterton, and Lake Brunner, showing that there is yet some establishment though insufficient for ragwort control. Enemies of the insect were the tachinid and hymenopterous parasites, and certainly the shining cuckoo, and in one locality at Feilding starlings were reported to have taken a heavy toll.

HYLEMYIA SENECEIELLA (Meade)

DESCRIPTION

The ragwort seedfly (*H. seneciella*) is a small, dull, greyish-pubescent insect, darker in the male, and 4 to 5 mm long (Fig. 23). It occurs in Great Britain and Europe. The eyes are bare and subcontiguous in the male, the frontal stripe being reddish brown and margined with blackish bristles; the sides of the front and cheeks are greyish yellow with silvery to blackish reflections; the epistome is slightly prominent, and the somewhat clavate palpi are black. The antennae are very short, the third joint being scarcely twice the length of the second, and the arista is sub-

pubescent with a swollen base. On the greyish-pubescent thoracic dorsum of the male are a central and two lateral dark-brown stripes, absent, or very inconspicuous, in the female; the scutellum is greyish-brown. The dark-brown legs are sparsely setose, and the small pulvilli are whitish. The wings are slightly clouded with brown, becoming yellowish toward the articulations; the third and fourth veins are almost parallel, while the anterior cross-vein is straight and at right angles to the fourth vein; the squamae are yellowish-white. The greyish abdomen is narrow in the male, but conical in the female, and there is a more or less distinct interrupted median stripe.

Another species very similar to *H. seneciella*, both in appearance and habits, and breeding in ragwort flowers, is *H. jacobaeae* (Hardy); it is recorded by Giard (1892), Meade (1892), and Collin (1936). Collin gave the following distinguishing characteristics:

H. seneciella

- (1) 4 to 5 mm long.
- (2) Arista subpubescent.
- (3) Sternopleural bristles 1:2, the lower anterior being absent.
- (4) Postero-dorsal preapical bristles of hind tibiae very small, or wanting.
- (5) Costa bare beneath.
- (6) Lobes of 5th abdominal sternite of male long and bare except for tuft of bristly hairs near base of each lobe, and a few shorter hairs towards the tip.
- (7) Ovipositor remarkably broad, dorso-ventrally flattened, with blunt and very short haired tip.

H. jacobaeae

- About 6 mm long.
- Arista more distinctly clothed with a longer pubescence.
- Sternopleural bristles 2:2.
- A transverse row of 3 mainly equal postero-dorsal preapical bristles on hind tibiae.
- Costa hairy beneath.
- Lobes of 5th abdominal sternite of male with an even distribution of bristles and hairs.
- Ovipositor also flat, but narrower with a more pointed and long haired tip.

The most contrasting of the above characters are (3) the sternopleural bristles, (4) tibial bristles, (5) hairiness of costa, and (6) the lobes of fifth abdominal sternite of the male. Of 296 flies that had emerged from a consignment all had the underside of the costa without hairs, but the sternopleural chaetotaxy varied; in 216 flies the formula was 1:2, in 69, 2:2; in one, 1:1; while opposite sides varied from 1:2 to 2:2 in five flies; 1:1 and 1:2 in one; and 2:2 and 3:2 in another; also the hind tibial characters are not clear. A study of the genitalia may reveal that more than one species has been imported into New Zealand.

BIONOMICS

Information on the bionomics of *H. seneciella* in Britain and Europe is limited. Giard (1892) in France, and Cameron (1935) at Farnham Royal both state that the fly begins to appear at the end of June, and that *H. jacobaeae*, also breeding in ragwort and very similar to *H. seneciella*, appears at the same time, while the larvae are in the capitula from July to August in Europe and England, and to late September in Ross-shire. According to both authors there are three larval instars. Mature larvae leave the florets to enter the ground for pupation; the insect hibernates as puparia. Collin (1936) stated that Hardy, in 1872, reported *H. jacobaeae* to have been very common in Berwickshire during the first and second weeks of August, and that the larvae were everywhere abundant in the flower heads of ragwort. This is mentioned here because it is possible that puparia of both species of seedfly were sent to New Zealand, though there can be no definite evidence until a more detailed examination is made of those imported flies that have been preserved.

H. seneciella oviposits in ragwort florets at all stages of opening (Fig. 24); it was found in New Zealand that unopened flower buds are sometimes infested. Usually a single egg is placed in each floret (Fig. 25); it soon hatches (in three to four days according to Cameron, 1935), and the larva moves downward to the developing seeds, eating them, and sometimes the receptacle of the floret as well (Fig. 26). Cameron stated that in the south of England 8% to 9% of the capitula are infested, and 75% of the seeds destroyed, but that in north Scotland infestation of capitula ranges from 33% to 34%. Kelsey (1955), who studied a New Zealand area after the insect had established itself, found that the percentage of infestation varied at different points and at different periods of flowering, ranging from 42% to 91% in 1950, and from 8% to 77% in 1954 of the early and main crops of flowers respectively, there being no infestation of the late crop. He also found that though a number of seeds per capitulum were not destroyed by the larvae, these seeds nevertheless failed to germinate, probably owing to immaturity and to the influence of a mould associated with larval frass in the flowers.

Some further information was gathered in New Zealand during the rearing of imported flies and their progeny, as well as from field observations after establishment of the insect.

(1) The longest life span recorded among the flies was 44 days; the proportion of sexes was never constant, one being in excess of the other, or both being in equal numbers.

(2) The emergence of flies from the larger consignments (7-14) continued through the New Zealand autumn and winter into the spring, there being a minor peak in the autumn and a major one in the spring. In the fairly large consignments (3 and 4) the peaks were in reverse order. In a comparatively small consignment (2) there were almost equal

emergences through winter and spring, and from two small consignments (5 and 6) flies emerged only in the autumn. Therefore, all the puparia except for those of the last two consignments (5 and 6) passed their normal winter, and some underwent a second winter in New Zealand; this may be normal or may have been due to the presence of puparia of another species, such as *H. jacobaeae*, among the consignments concerned. In the field where the insect had definitely established itself, infested flowers in different localities were found from March to July and from December to February, and it is possible that infestation occurred in some of the other months.

(3) Infestation is indicated by a dark spot on the disc of the floret, and adjoining florets tend to become matted together by larval secretion, as was also noted by Cameron (1935). Another characteristic of infestation is that the pappus is prematurely extruded (Fig. 27) as a brownish, or whitish, brush-like structure that is inclined to be sticky.

(4) Some infested florets wilted and were abandoned by the immature larvae, which entered and completed their development in healthy florets when these were presented to them.

(5) An attempt was made to secure some details on a complete cycle from progeny of flies emerging from consignments. For example, from 18 to 21 March (autumn) flies were encaged with flowers, and mating and oviposition was observed from 28 March until early June (mid winter). On 3 April, larvae in the earlier instars were found, and mature ones commenced to leave the flowers on 30 June (mid winter). Pupation took place from 5 July, and flies emerged from 13 November; in the field, flies in an area of establishment were recorded during November.

These records indicate the duration of each stage (except incubation, which Cameron (1935) stated was from three to four days); the first dates are taken in each case: from oviposition to larvae leaving the flowers, 94 days; from leaving the flowers to pupation, five days (yet, during the warmer November, there is a record of this period having been from 10 to 17 days); from pupation to fly emergence, 131 days, giving a total of 230 days, later winter and spring intervening. In another series of observations, for which capitula were marked after oviposition on 23 February, mature larvae were present on 31 March, pupation was observed soon after in April, and flies emerged in December, the whole covering a period of some 323 days, including winter; in this instance the period of development between oviposition and larval maturity was 36 days, but it took place during the mild, even warm, temperatures of March. There is also a record of an autumn infestation having given rise to a spring generation after 199 days, but there are no details. On the other hand, incomplete data concerning a spring infestation, under quarantine conditions, indicate that the cycle could be comparatively brief (within four and five months).

CONSIGNMENTS

Fourteen consignments containing 840,357 puparia were imported from England in 1928, 1931, 1932, 1934–1936, and 1939; 2,000 of these puparia were sent to Australia in 1932, and from the balance 155,114 flies emerged, i.e. 18.5% of the puparia developed; there were also 11,894 parasites (i.e. individuals), but as one or more emerged from a single puparium and as one species, at least, was hyperparasitic the percentage in relation to puparia cannot be assessed.

The consignments had been collected in August, September, October, and November, the first six in the field and the remainder from larvae after the latter had emerged from flowers brought into the laboratory. Particulars of the consignments are given in Table 10.

TABLE 10. *Hylemyia seneciella* and parasites.

Consign- ment	Date Collected	Date Received	Puparia	Number		
				Flies	%	Parasites
1	Oct 1928	15 Dec 1928	200	2	1	0
2	Nov 1931	20 Jan 1932	3,000	948	31.33	57
3	Aug 1932	2 Nov 1932	31,250	5,839	11.00	3,899
4	Sep 1932	16 Nov 1932	21,750			
5	Oct 1934	11 Dec 1934	157	47	30.00	0
6	Aug 1935	30 Oct 1935	7,000	1,378	19.70	53
7	Aug 1936	15 Oct 1936	250,000			
8	Aug 1936	22 Oct 1936	150,000	94,173	17.12	2,975
9	Sep 1936	4 Nov 1936	90,000			
10	Sep 1936	28 Nov 1936	60,000			
11	Aug 1939	30 Sep 1939	45,000	52,727	23.43	4,910
12	Aug 1939	20 Oct 1939	80,000			
13	Sep 1939	31 Oct 1939	75,000			
14	Sep 1939	12 Nov 1939	25,000			
		Totals	838,357	155,114	18.5	11,894

TECHNIQUES OF SHIPPING AND REARING

SHIPPING

The puparia were packed for shipment to New Zealand in four ways in glass-topped tins: (1) among sterilised damp sphagnum moss; (2) between layers of blotting paper and cotton wool; (3) between layers of filter paper; (4) on filter paper lining the bottom of the tins and covered with shredded paper, the tins of each consignment being packed among moss in wooden containers. There are no data for the 1st consignment, but for the rest the method of packing apparently had no influence on the viability of the puparia, as the percentages of fly emergences fluctuated irrespective of the method, as follows: (1) 2nd consignment, 31.33%; 3rd and 4th consignments, 11%; (2) 5th consignment, 30%; (3) 6th consignment 19.75%; (4) 7th to 10th consignments 17.12%; 11th to 14th consignments 23.43%.

REARING

On removal from cool store the puparia were set out for emergence of flies. For the small first consignment, a standard darkened emergence box, having glass collecting tubes projecting from the sides, was used. For the larger consignments of 1932, 1934, and 1935, and in order to simulate the natural habitat of the puparia as much as was practicable, flower pots were adapted as emergence containers. They were half filled with sphagnum moss tightly packed and covered with a layer of fine river sand on which the puparia were placed beneath a covering of moss; the mouth of each pot was enclosed by a tarboosh-like muslin bag, tightly fitting and sealed to the rim by adhesive tape; the pots were stood in trays of water, the foundation of moss absorbing sufficient moisture to keep the overlying sand adequately damp. As the flies emerged they were collected from the muslin bags.

Because the flower pots were not altogether satisfactory (especially in the presence of emerging parasites), and in preparation for the better handling of the greater number of emergents expected from the much larger consignments during 1936, Messrs J. M. Kelsey and C. H. G. Fraser designed another type of emergence container and 200 were manufactured. This type (Fig. 22) consisted of three parts as follows:

- (1) A zinc can 6 in. high, with a diameter of 9 in., to the mouth of which was soldered a flange consisting of a $10\frac{1}{2}$ in. square sheet of zinc, the centre having been removed to correspond with the mouth of the can.

- (2) A cone of phosphor bronze gauze $6\frac{1}{2}$ in. high, having a $1\frac{1}{4}$ in. opening at the apex carrying a zinc collar 1 in. high, the whole attached to a flange similar to that on the can.

- (3) A tubular celluloid trap, about 6 in. long and having one end closed with voile (Fig. 15); into the open end there closely fitted a celluloid collar carrying a short voile cone, open at the apex, projecting into the trap, whose internal diameter with the collar and cone inserted was sufficient to allow it to fit firmly over the metal collar at the apex of the phosphor bronze cone.

Each can was more than half filled with fine river sand in which layers of puparia were spread; the phosphor bronze cone was then placed in position with its flange upon that of the can, the flanges being bound with adhesive tape over which V-shaped strips of zinc were fitted on each side; the assembled units were arranged in an insect-proof insectary. Requisite moisture for the puparia buried in the stand was applied through the phosphor bronze cones by means of an atomiser sprayer.

As the flies emerged they were released in both the muslin-covered and trough-type of cages enclosing flowering ragwort in the insectary (see under *Tyria*). It was soon found, however, that the flies required more space and light than was provided by the cages; so they were freed in insect-proof insectaries where ragwort had been planted and

was flowering. When more precise observations were required than could be made under the insectary conditions, large cages were used; these were covered with steel-wire gauze having a mesh of 16 to the linear inch that let in adequate light. The flies were provided with a dilute solution of brewer's yeast, pollen, and honey; cotton wool was soaked in this and fixed to the top of the cages where the flies tended to congregate.

Flowers were marked and dates noted when oviposition was observed; some of these flowers were examined from time to time and the insect's development noted. For collecting mature larvae as they left the capitula, Mr C. G. H. Fraser developed a technique by which each capitulum was enclosed in a celluloid tube having one end covered with voile and the other plugged with a split cork through which the stem of the capitulum passed. As each larva left the flower it was collected from the tube, and placed in a container with damp sand into which it burrowed for pupation; fly emergence was noted in due course.

TESTS ON PLANTS OTHER THAN RAGWORT

Laboratory starvation and preference tests with *H. seneciella* were undertaken on cultivated Compositae and weeds. The only composites cultivated in New Zealand are lettuce, artichoke, sunflower, and garden flowers; these and native *Celmisia* were included in the tests with groundsel, oxeye daisy, common daisy, dandelion, sow-thistle and cat's ear. There was neither oviposition nor larval attack in any of the flowers, and the fly forsook the composites in the presence of ragwort. Larvae that were transferred from ragwort flowers to others of that weed completed their development, but perished when they were transferred to any other species of the composites tested; for example, when placed on the disc of the daisy the larvae burrowed downward to the seeds but there died without attacking them.

HISTORY OF CONSIGNMENTS

The consignments had been collected in England in the months from August to November, at a time when puparia were present in the field and when sufficiently mature larvae were available in the flowers for puparia to be reared in the laboratory. The data on the history of the consignments are rather limited.

First Consignment. This was received during December 1928 and contained 200 puparia apparently in good condition; there is no record of how they had been packed. They were set out in a rearing box on their arrival and submitted to summer temperatures, so their normal hibernation was shortened. Only two flies, both males, emerged, one in March and the other in April 1929, but both died just after emergence.

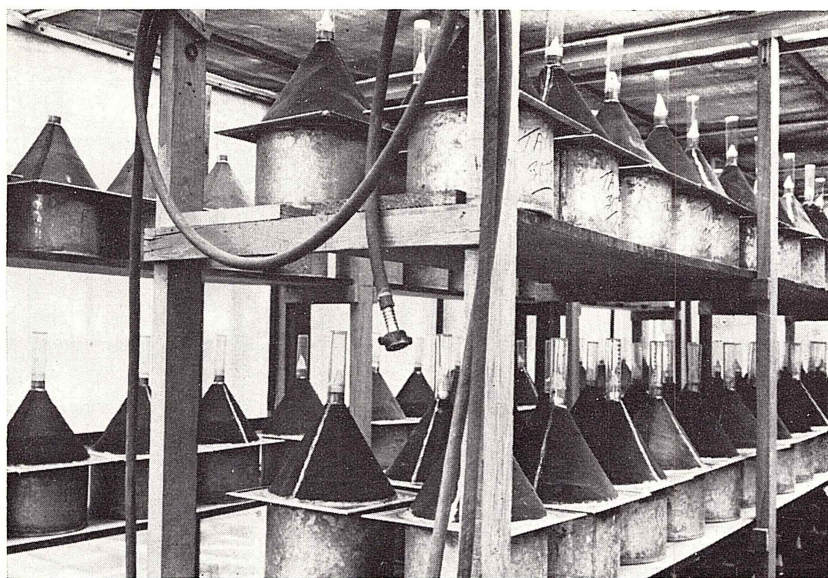


FIG. 22. Battery of cans and traps for emergence of *Hylemyia seneciella*. (W. C. Davies photo.)

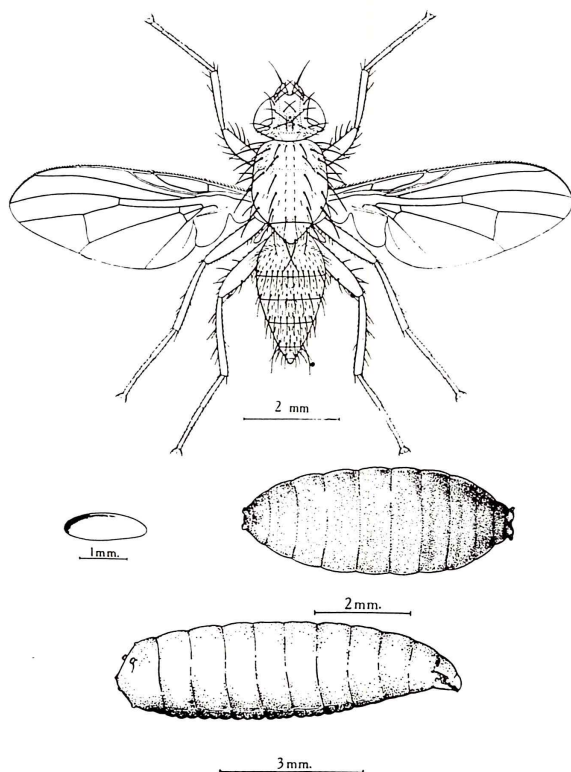


FIG. 23. *Hylemyia seneciella*; adult, egg, larva, and pupa. (After P. Cameron, 1935.)

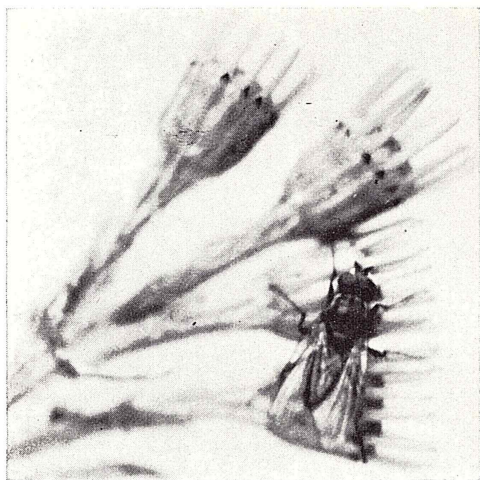


FIG. 24. *Hylemyia seneciella*; adult on ragwort florets. (W. C. Davies photo.)

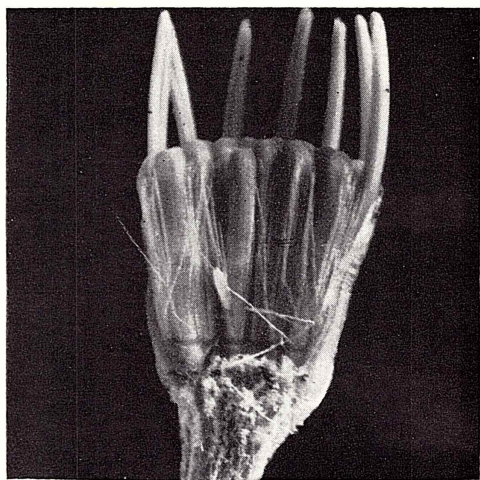


FIG. 25. *H. seneciella* egg in ragwort floret. (W. C. Davies photo.)

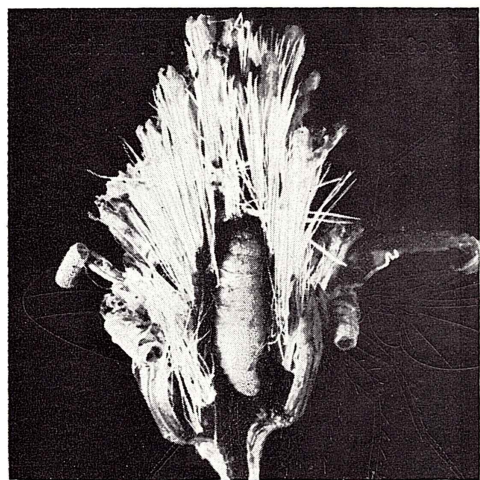


FIG. 26. Larva of *Hylemyia seneciella* in ragwort floret showing extruded pappus and destruction of seeds. (W. C. Davies photo.)

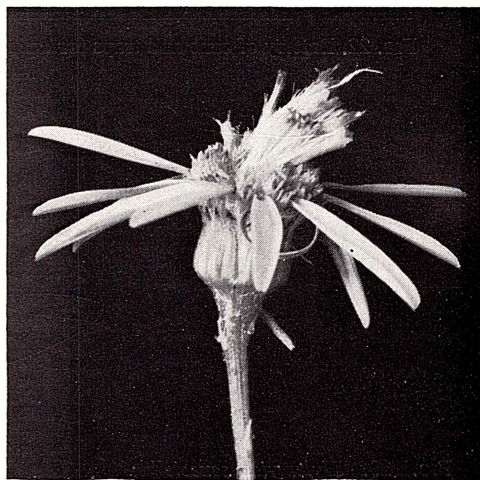


FIG. 27. Ragwort floret infested by *H. seneciella* larva – note extruded pappus. (W. C. Davies photo.)

FIG. 28. *Chrysomela hyperici*; beetle and larva. (After F. Wilson, 1943.)

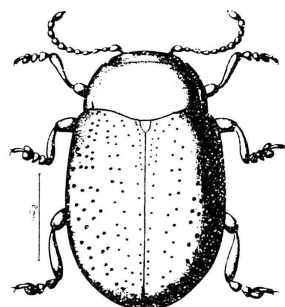
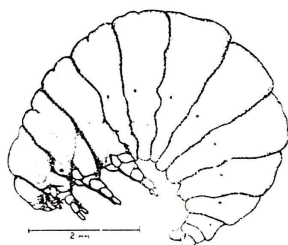


FIG. 29. *Chrysomela hyperici* beetles, $\times 1$. (W. C. Davies photo.)



FIG. 30. Cluster of *Chrysomela hyperici* beetles attacking St John's wort. (D. Read photo.)



FIG. 31. Effect of *Chrysomela hyperici* on St John's wort. (D. Read photo.)

Second Consignment. The 2nd consignment of 3,000 puparia arrived in January 1932 at the close of their normal hibernation; they had been collected during the English winter, in the last week of November 1931, and were packed in damp sphagnum moss in small glass-topped boxes, 250 specimens in each box.

At the close of January the puparia were removed from cool store and placed in the flower-pot-type of emergence cage under summer conditions. During March (from the 22nd) there was a daily emergence of flies, totalling 34 (31 males and three females). Flowering ragwort was enclosed in three breeding cages; in each of these a female was placed together with the males proportionately divided. Emergences from the consignment continued through winter into November (early summer) as follows: April 141, May 199, June 128, July 32, August 30, September *nil*, October 186, November 198, giving a total of 948 flies (473 males and 475 females), 31.33% of the consignment; there were also 57 parasites. As with the flies first to emerge in March, those emerging later were caged with flowering ragwort, but there was no apparent infestation, and no progeny developed.

As in the 1st consignment, the first flies emerged towards the end of March, about three months earlier than their normal first appearance at the end of June in England as recorded by Cameron (1935). Perhaps this was due to the summer and autumn conditions of New Zealand to which they had been submitted; but that emergences continued through the winter, fell off in July, ceased in September, and upsurged during October and November (during part of which period they would have been occurring in England) is a matter of interest, the pupal period having been long—through two winters for some individuals.

Third and Fourth Consignments. The 3rd consignment was received on 2 November and the 4th on 16 November, 1932; the former contained 31,250 puparia, and the latter 23,750, of which 2,000 were forwarded to Canberra in Australia, leaving 21,750 of that consignment for study. These consignments had been collected in the autumn (late August and early September respectively) and were packed in sphagnum moss in glass-topped tins. The remaining 53,000 puparia of the two consignments were dealt with as a whole and were divided into seven lots; these were held in cool store at 40° F for periods ranging from 11 to 25 weeks (including the period in transit), the first lot being removed for fly emergence early in December 1932, and the last at the close of January 1933.

A total of 5,839 flies (11% of the puparia) and 3,899 parasites emerged, the flies from February to November 1933, and the parasites from February 1933 to February 1934 (inclusive). Emergences were most numerous during March, April, and May (part autumn and early winter), falling in June and July, to almost none in August and September, but reaching a minor peak in October and November before ceasing. On the other hand, though the parasites emerged continuously in small numbers from February to November, there was a major

surge during December 1933 and January 1944 after the final fly emergences, and an abrupt fall before emergence ceased in February.

Though no records are now available on when flies emerged from puparia in each lot of the seven held for different periods in cool store, the percentages after 11, 13, 16, 22, 23, 24 and 25 weeks were 18.8, 18.3, 31.8, 21.8, 17.8, 4.8 and 0.48 respectively. In any case, it is to be noted that some puparia had passed their normal winter of 1932-33, as well as the New Zealand winter and spring, before the last flies emerged in early summer (November) of 1933, while other puparia continued to produce parasites in early autumn (February) of 1944. The results with the 7th to 10th and 11th to 14th consignments are of interest in this respect.

From the flies that had emerged in March from the English material, 58 larvae were taken for observation, 50 prior to, and eight during, spring 1933; 27 produced puparia, from all of which flies emerged in November. The cycle from one fly emergence to another took eight to nine months, and flies were observed to live up to 15 days.

Mating and oviposition by the English flies were noted in March, larvae of different stages were found during April, May, and June, and pupation was first noted at the beginning of July. After winter, the English flies, which had not ceased to emerge, except virtually so during August and September, were ovipositing in October until December, and larvae of different stages were found up to the end of November when puparia were found, pupation taking place from 10-17 days after the larvae had entered the ground.

Fifth Consignment. This had been collected in October 1934 (during the late mid autumn) and reached Nelson on 11 December. The consignment consisted of 157 puparia and six larvae. The larvae had been packed among pieces of blotting paper in a glass tube but were dead on arrival. The puparia had been placed between layers of blotting paper and cotton wool in glass-topped boxes; except for five attacked by fungus and four that were shrivelled, they seemed to be in good condition and were placed out on arrival for emergence of flies. Thus the period under cool store was about eight weeks, of which two were of the normal wintering.

Only 47 flies (21 males and 26 females) were secured from the 157 puparia, three emerging in January and 44 in March 1935. All died without reproducing, though attempted oviposition was noted; all the remaining puparia died. There were no parasites.

Sixth Consignment. This was collected in August 1935 at the close of the English autumn, and reached Nelson on 30 October, having been submitted to an out-of-season period under cool store of seven weeks during transit. The 7,000 puparia it contained were packed between layers of filter paper in tins, which were surrounded by slightly dampened sphagnum moss in a wooden box.

On receipt the puparia were placed out for emergence of flies which commenced at the close of January 1936 and reached a peak about the middle of February, afterwards gradually decreasing until the last

week in May. The sequence was as follows: January, 65 (26 males, 39 females); February, 968 (462 males, 506 females); March, 261 (127 males, 134 females); April, 66 (26 males, 40 females); May, 18 (six males, 12 females), giving a total of 1,378 flies, or 19.7%. The flies oviposited when caged with ragwort. Of parasites, 53 braconids were secured (23 in February, 29 in March, one in April). After May many apparently healthy puparia remained, but there are no records of further emergences.

On 23 February capitula were marked after oviposition had been observed, and on 6 March developing larvae were found. The capitula were then enclosed in celluloid capsules, and 23 fully grown larvae were recovered at the close of March; 81 were obtained in April and 18 in May. These larvae were placed in sandy soil, and pupation commenced in April; 117 puparia were recovered, and gave rise to a New Zealand generation of 67 flies (36 males, 31 females), which emerged throughout December and were observed to oviposit in ragwort flowers.

Seventh to Tenth Consignments. These consignments contained a total of 550,000 puparia collected during the English autumn, the 7th and 8th in August and the 9th and 10th in September; the former were received in October and the latter in November 1936.

The puparia were packed in glass-topped tins having filter paper on the bottom on which the puparia were placed and covered with shredded paper to keep them in position. They were packed in lots of 150, 250, 500 and 1,000 per tin. Mould had developed in half of the containers in which there were less than 1,000. It is not known what proportion of the puparia was seriously affected by the mould, as flies emerged after the infested puparia were treated with a saturated solution of boracic acid, a method found effective when dealing with diseased larvae and pupae of *Rhyssa persuasoria* (L.).

As attention was then being given solely to the field liberation of flies, these consignments were treated as a group. The removal of such a large number of puparia from cool store for emergences occupied some time; a start was made as soon as possible after each consignment was received, the work being completed with the 10th consignment early in December 1936. No records were kept of emergences from individual consignments; the puparia were distributed among 200 emergence cans.

The flies secured totalled 94,173 (17.12% of the puparia); the number of each sex recorded up to the end of September 1937 (after which separate records were not kept) was 23,372 males and 17,555 females. In addition 2,975 parasitic insects emerged. (See Table 11.)

Notable features concerning the puparia of the 7th to 10th consignments (collected in the English autumn, 1936), none of which had been in cool store for less than 10, or more than 12 weeks, were, (1) that fly emergence commenced in the New Zealand early summer (November) 1936, and continued till early autumn (February), 1938; (2) that some had not passed their normal winter period before fly emergences; (3) that some had produced an ever increasing number of flies through-

TABLE 11. *Hylemyia seneciella* and Parasites

Months	Flies	Parasites					
		Bracon- idae	Chal- cididae	Ichneumon- idae	Diptera	Proctotryp- idae	Pteromal- idae
1936							
Nov	8	4	1				
Dec	41		2	1	51		
1937							
Jan	35	7		2	8		
Feb	1,592	991	4	10	33	7	1
Mar	8,709	527			1	63	7
Apr	5,682	872					13
May	4,735	106					6
Jun	3,425						1
Jul	2,110						
Aug	2,384						
Sep	12,206						
Oct	39,139	1					
Nov	13,454				1	69	
Dec	649	56			24		
1938							
Jan	2	39					
Feb	2	66			1		
Totals	94,173	2,669	7	13	119	139	28

out the summer, autumn, winter and early spring; and (4) that others had passed these seasons and produced a major surge of flies from mid spring to early summer (September to November), after which the emergences had abruptly fallen off.

On the other hand the major emergence of parasites (especially Braconidae) was during autumn and early winter, the numbers recorded being of individuals and not of species. Cameron (1935) recorded *Phaenocarpa ruficeps* Nees (Braconidae), *Hemiteles fulvipes* Grav., a hyperparasite (Ichneumonidae), and *Lamprotatus splendens* Westw. and *L. obscurus* Walk. (Pteromalidae), all of which were secured from the imported puparia, in addition to the Chalcididae, Proctotrypidae, and Diptera, which were not identified and not mentioned by Cameron.

Eleventh to Fourteenth Consignments. The work with *H. seneciella* had ceased in 1937 with the successful establishment of the insect in the field. However, as difficulties arose over access to the main establishment block of ragwort near Putaruru, it was considered necessary to import more puparia in order to establish the flies in another ragwort area on abandoned Crown lands. Four consignments collected in August and September during the English autumn of 1939 reached Nelson between 30 September and 12 November. They were packed in the same way as the 7th to 10th consignments, and contained

225,000 puparia, which were held in cool store, some for at least 20 and some for at most 23 weeks including the period in transit. The 11th consignment was placed out for emergence on 20 December 1939, the 12th on 10 January, and the 13th and 14th at the end of February 1940. Emergences began at the close of January, becoming very numerous in late summer and autumn; at the end of this season flies ceased to emerge, though parasites became abundant; 52,727 flies were obtained and liberated, and 4,910 parasites emerged.

LIBERATION AND ESTABLISHMENT

Liberation. A general liberation throughout the ragwort areas of the country was not contemplated; the first objective was to ensure establishment by concentrating the insect on a few selected areas, from which foci the fly would gradually spread locally and be collected for wider distribution.

Liberation of flies commenced in February 1936. On the 15th of that month 612 insects (of about equal number of sexes) were freed on ragwort growing in the Cawthron Institute grounds, and 52 at the northern boundary of the Motueka Borough a week later; at the same time and until April, liberations were made in the Te Awamutu Scenic Reserve and on Section 7, Block V, Patetere Survey District in the North Island, near Putaruru, the latter having been selected as the main establishment area owing to the favourable state of the weed there throughout the year; 1,378 flies were liberated in 1936.

During 1937 approximately 92,470 flies were liberated, 80,000 of them having been concentrated on the Putaruru establishment area, and the remainder on areas at Coromandel, Matamata, Tirau, Ohinemuri, Opotiki, Paeroa, Te Awamutu and Waipa Counties in the North Island, and at the Cawthron Institute and a selected area at Tui, near Nelson. The 1937 liberations were carried out from February to May and from July to December.

From February to April 1940 a total of 52,727 flies was concentrated on an abandoned farm on Crown lands (Section 4, Block III, Horohoro Survey District), which lies on Mt Ngongotaha near Rotorua.

Establishment. Owing to lack of facilities, the field establishment of *H. seneciella* was not followed in any detail until some years after liberation; however, records are available of some observations made during the earlier years as circumstances allowed.

An aspect that had to be borne in mind when infestation of flowers was discovered in the field in the same years that flies had been released, was that the larvae could have been from a generation of flies arising from liberated ones, or simply the progeny of the latter. Therefore, when considering the problem of establishment it had to be remembered that liberations were made during the autumn (February to April) of 1936, and early in 1937 (autumn) as well as from late winter to early summer (July to December) and that there were no

further liberations until the autumn of 1940, and then only on the Crown lands area at Ngongotaha.

From March to July, and again from November 1937 to February 1938, infested flowers occurred at the Cawthron Institute, at Tirau, and at the Putaruru establishment area; at the last place, in November 1937, infestation was found over 100 acres, and in February 1938, 50% of the flowers contained larvae, while thousands of puparia occurred in the ground. These infestations at both the Cawthron Institute and Putaruru could have arisen from flies liberated from the late winter to early December of 1937, or from a New Zealand generation produced by the autumn liberations of 1936 and 1937, or from both sources.

In December 1939, and January 1940 and 1941 at Putaruru, there was a summer infestation that could have arisen only from a New Zealand generation, because no flies had been liberated in 1938 and 1939. Similarly, a New Zealand generation must have given rise to a winter infestation recorded during June 1940 at the Cawthron Institute. In January 1941 and 1942, there was a summer infestation of nearly mature larvae at Ngongotaha, doubtless the progeny of generations arising from the autumn liberations of 1940. In 1944 and 1945 the fly was well established at the Cawthron Institute and Putaruru; at Ngatira (Redwoods Plantation, Matamata County) Kelsey (1955) surveyed the position in February 1950 and in 1954, and reported that 91% of the florets of the early flowering were infested, 42% of the main flowering, and none of the late flowering in 1950, and 8% and 77% of the early and main flowering in 1954. In 1950 nothing was found at Ngongotaha, the area having been grazed by cattle and sheep. In January 1958 the Entomology Division, Department of Scientific and Industrial Research, collected a shipment of 4,000 puparia for Australia; these were obtained at the Redwoods Plantation, where the infestation was found to be lower than during 1950 and 1954 (Hoy, 1958).

ST. JOHN'S WORT

Hypericum perforatum L.

INTRODUCTION

St. John's wort is a weed of considerable importance particularly in the higher regions of low rainfall in New Zealand; it may even occur in dense growths covering considerable areas and so displacing pasture. It is harmful to livestock, owing to its content of hypericin, which induces a photo-sensitisation and dermatitis, particularly of the ears and muzzle of unpigmented sheep.

As the control of this weed was a major project in Australia, and as the Commonwealth had undertaken special research on insects attacking the plant in Europe, it was decided not to duplicate the basic studies in New Zealand, but to depend upon the findings from the Commonwealth research and secure supplies of any proved insect from Australia. Of insects that had been so studied and established, only the chrysomelid beetle, *Chrysomela hyperici* Forst., was brought to, and released in, New Zealand.

CHRYSOMELA HYPERICI Forst.

DESCRIPTION

Chrysomela hyperici is about $\frac{1}{4}$ in. long (Fig. 28, 29); it is a broadly ovate beetle, strongly arched dorsally, and resembles a large ladybird in shape. The colour is a brilliant, deep bluish-green, but some are of a copper and others of a purple tone. The following description is taken from Wilson (1943).

"Length about 6 mm; the gross punctures on the elytron about 0.08 mm in diameter at the centre but smaller towards the margins; distance between the punctures in the same row 1 to 4 or more times, between rows of the same pair less than 1 to 2 times, and between the rows of adjacent pairs 2 to 3 times the diameter of the punctures; number of punctures in each row 11 to 16, the centre rows having about 11 and the other rows several more; aedeagus in male 1.75 mm long, strongly curved, much produced posteriorly where it terminates in a spatula."

BIONOMICS

Clark (1953) studied the bionomics of *C. hyperici* in Australia, and as far as can be judged from the limited observations in New Zealand the cycle is virtually the same in both countries. The beetles appear in the spring, are very abundant on St. John's wort in Decem-

ber, and attack the weed for about six to eight weeks; they are gregarious, and many thousands can be collected within 15 minutes by shaking the plants over a sheet on the ground. In December the beetles commence to leave the plants to aestivate among the debris on the ground, where they remain until autumn (about March), when they ascend the drying stems. Mating takes place and the beetles again descend to lay their eggs on the underside of the procumbent foliage at the base of the plants; the eggs are a conspicuous orange colour, and in the upper Awatere Valley they were common in April 1945. The larvae (Fig. 28) devour the procumbent foliage and buds during winter and spring, and when mature enter the soil to pupate at a depth of 2 in (Clark, 1953). The major beetle invasion of the weed is in December, hordes of the insects being present and the plants black and weighed down with them (Fig. 30, 31). The beetles spread rapidly even over considerable distances; e.g., near Arrowtown they had extended over the Crown Range (2,000 ft elevation) into the Cardrona Valley.

LIBERATION AND ESTABLISHMENT

In December 1943, some 30,000 *C. hyperici* beetles were sent by air from Canberra and were received on the 17th. On the following day, after the necessary check in quarantine, liberations were made on a dense and extensive stand of St. John's wort on Mr J. Stevenson's property at Middlehurst in the upper Awatere Valley (Marlborough). In the following December (1944), the insect had become established and was very numerous, having completely cleared areas of the weed up to 80 square yards in extent. By December 1945 the cleared areas were much more extensive, and at the same time in 1946 there was a sufficient beetle population from which collections were made for despatch to weed infested areas at Cromwell and Arrowtown in Central Otago. Over 400 acres of the weed had been cleared and replaced by pasture in the upper Awatere by December 1947, and the plants surrounding the cleared area were literally weighed down by the clustering beetles; indeed, the insects were crushed underfoot as one walked on the recently cleared ground behind the advancing hordes.

When the beetles were received from Australia, no St. John's wort was available in Nelson to use as food in the containers when the insects were transported to the upper Awatere Valley. Tutsan (*Hypericum androsaemum* L.) was used, and the beetles ravenously devoured the leaves and stripped the bark. Because of this, and as tutsan is a common weed in areas of higher rainfall, the beetle liberations after 1947 were to areas infested by both St. John's wort and tutsan. The beetle failed in all places against the latter, but when it was liberated in 1949 in the Kawhia district and at Ihakara, near Levin (North Island), and in the Buller Gorge (South Island), it attacked the weed in the same way as it had done in the containers; by 1950, however, it had apparently disappeared.

The beetle was liberated against both weeds in the following places during 1948, 1949, and 1950, after which consignments were sent further afield from Arrowtown and the Awatere Valley.

Against St. John's wort. 1948, Ripponvale (Alexandra), Lower Shotover, Skippers, Wanaka Flats, and Harveys Flat, in Otago; 1949, Cromwell, Arrowtown, Omarama and Lake Pukaki, in Otago, Tenga-wai Bridge near Fairlie, Culverden, Rotherham, and Hawkeswood, in Canterbury, and near Hastings in Hawke's Bay.

Against tutsan. 1948, Maungatua (Taieri), Glenhope (Nelson), and Greymouth (Westland), in the South Island, and Dannevirke, Te Kuiti, and New Plymouth, in the North Island; 1949, the Galatea, Taupo, Rotorua, Takapau, Marton, Wairarapa, and Uruti districts, in the North Island; 1950, Marlborough Sounds, Buller Gorge, and Puerua near Balclutha, in the South Island, and Ihakara near Levin, Hamilton environs, and Matarawa near Greytown, in the North.

It is obvious from the available records that *Chrysomela hyperici* is capable of effectively controlling St John's wort, as is clearly demonstrated in the upper Awatere Valley where extensive areas of the weed have been cleared and so held over the years (from 1944 to 1960). However, in some other locations on which data are available the position does not seem to be satisfactory; for instance, at Arrowtown, where the weed had been cleared after the beetle's establishment in 1947, considerable regrowth has recurred, and at Omarama, though the insect was successful for the first two years after liberation in 1949, it has not been seen since.

REFERENCES

- ANONYMOUS 1927: Noxious Weeds Investigations. *A. Rep. N.Z. Dep. scient. ind. Res.*, p. 3.
- 1928: Noxious-weeds-control Research. *Ibid.*, pp. 7-8.
- 1938: *Apion ulicis*. *N.Z. Jl Agric.* 56: 79.
- ALLAN, H. H. 1940: A Handbook of the Naturalised Flora of New Zealand. *Bull. N.Z. Dep. scient. ind. Res.* 83.
- 1961: "Flora of New Zealand Vol. 1." Government Printer, Wellington. 1,085 pp.
- BARNES, H. F. 1948: "Gall Midges of Economic Importance. Vol. 3. Fruit." Crosby Lockwood, London, 184 pp.
- BENTHAM, G. 1864: "Flora Australiensis. Vol. 2." Reeve, London, 521 pp.
- CAMERON, E. C. 1935: A Study of the Natural Control of Ragwort (*Senecio jacobaea* L.) *Jl Ecol.* 23: 266-322.
- CARPENTER, G. D. H. 1936: A Note on the Behaviour of New Zealand Birds toward the Cinnabar Moth (*Tyria jacobaeae* L.). *Entomologist's mon. Mag.* 72: 162-3.
- CHATER, E. H. 1931: A Contribution to the Study of the Natural Control of Gorse. *Bull. ent. Res.* 22: 225-35.
- CHEESEMAN, T. F. 1925: "Manual of the New Zealand Flora". 2nd ed. Government Printer, Wellington, 1,163 pp.
- CLARK, L. R. 1953: The Ecology of *Chrysomela gemellata* Rossi and *C. hyperici* Forst., and Their Effect on St John's Wort in the Bright District, Victoria. *Aust. Jl Zool.* 1: 69.
- COCKAYNE, A. H. 1912: The Blackberry Bud-moth. A Promising Agent for Control. *N.Z. Jl Agric.* 5: 372-4.
- COLLIN, J. E. 1936: A Note on Anthomyidae (Diptera) Reared from the Flower Heads of *Senecio*. *Entomologists' Rec. J. Var.* 48: 53-4.
- COTTIER, W. 1931: The Blue Stem-borer of Ragwort (*Homoeosoma vagella*). *N.Z. Jl Agric.* 42: 333-7.
- 1953: Aphids of New Zealand. *Bull. N.Z. Dep. scient. ind. Res.* 106.
- CUNNINGHAM, G. H. 1922: A Fungus Disease Attacking Blackberry. Identified as Raspberry Cane-wilt. *N.Z. Jl Agric.* 24: 23-6.
- 1927: "Natural Control" of Weeds and Insects by Fungi. *Ibid.* 34: 244-51.
- CURRIE, G. A.; GARTHSIDE, S. 1932: The Possibility of Entomological Control of St John's Wort in Australia. Progress Report. *Pamph. Coun. scient. ind. Res. Aust.* 29.
- DAVIES, W. M. 1928 a: Notes on the Feeding Habits of *Habrosyne derasa* L. (Lepidoptera). *Bull. ent. Res.* 19: 267-70.
- 1928 b: The Bionomics of *Apion ulicis* Forst. (Gorse Weevil), with Special Reference to its Role in the Control of *Ulex europaeus* in New Zealand. *Ann. appl. Biol.* 15: 263-86.
- DAWSON, J. W. 1960: Natural *Acaena* Hybrids in the Vicinity of Wellington. *Trans. R. Soc. N.Z.* 88: 13-27.
- DUMONT, C. 1928: Expériences sur la Modification Profonde du Régime Alimentaire des Diverses Chenilles. *Annls Soc. ent. Fr.* 97: 59-104.
- FUENTES, F. 1929: Sobre las Acaenas y la Lana. *Revta chil. Hist. nat.* 32: 55-6.
- GÉNIEYS, P. 1927: Un Ennemi des Rosiers le *Coraebus rubi*. *Annls Épiphyt.* 13: 48-78.

- GIARD, A. 1892: Les Observations suivantes sur l' Ethologie de *Phorbia seneciella* Meade. *Bull. Soc. ent. Fr.* 2 (7): cxvii-cxx.
- GOURNEAU, M. 1845: Lettre sur les Insectes aux Environs de Cherbourg. *Ibid.* 3(2), p. lxxix.
- 1847: Note pour servir à l'Histoire des Insectes qui vivent dans les Gousses du Genêt Épineux (*Ulex europaeus*). *Annls Soc. ent. Fr.* 5 (2): 245-53.
- GOURLAY, E. S. 1930: Preliminary Host-List of the Entomophagous Insects of New Zealand. *Bull. N.Z. Dep. scient. ind. Res.* 22.
- HAMILTON, AVIS 1949: The Blackberry Mite (*Aceria essigi*). *N.Z. Jl Sci. Technol.* A31 (2): 42-5.
- HARVEY, W. H.; SONDER, O. W. 1864: "Flora Capensis. Vol. 3." Hodges Smith, Dublin, 633 pp.
- HOFFMANN, A. 1950-58: *Faune Fr.* 52, 59, and 62, Coléoptères Curculionidae.
- HOOKE, J. D. 1867: "Handbook of the New Zealand Flora". Reeve, London, 798 pp.
- HOY, J. M. 1958: The Collection of *Hylemyia seneciella* (Meade), (Diptera, Muscidae), for Shipment to Australia. *N.Z. Jl Sci.* 1: 417-22.
- IMMS, A. D. 1929: Remarks on the Problem of the Biological Control of Noxious Weeds. *Proc. 4th int. Congr. Ent.*, 2: 10-17.
- JANVIER, H. 1933: Étude biologique de quelques Hyménoptères du Chile *Annls sci. nat. (Zool.)*, Sér. 10, 16: 209-356.
- JOSEPH, C. 1928: Sobre Acaenas de Chile. *Revta univ. Santiago* 13: 105.
- 1929: Un Parasite de les *Acaena* el *Antholcus varinervis* Spi. *Ibid.* 14: 708-26.
- 1935: Insectos Chilenos para Nueva Zelandia. *Ibid.* 15: 862-7.
- KELSEY, J. M. 1937: The Ragwort Leaf-miner (*Phytomyza atricornis* Mg.) and its Parasite (*Dacnusa areolaris* Nees). *N.Z. Jl Sci. Technol.* 18: 762-7.
- 1945: A trap for Collecting Ground-pupating Insects. *Ibid.* A26: 294-7.
- 1955: Ragwort Seed-fly Establishment in New Zealand. *Ibid.* A36: 605-7.
- KLOET, G. S.; HINCKS, W. D. 1945: "A Check List of British Insects". Stockport, 483 pp.
- MEADE, R. H. 1892: La Description d'un Diptère nouveau de la famille des Anthomyidae. *Bull. Soc. ent. Fr.* 2(7): cxvi-cxvii.
- MILLER, D. 1928: Piri-piri Control: an Insect Parasite. *N.Z. Jl Agric.* 37: 49.
- 1929a: Control of Ragwort: Experimental Work with the Cinnabar Moth. *N.Z. Jl Sci. Technol.* 11: 112-9; (also in *N.Z. Jl Agric.* 39: 9-17).
- 1929b: Noxious Weeds Control Research. *A. Rep. N.Z. Dep. scient. ind. Res.*, pp. 18-19.
- 1930: Noxious Weeds Control Research. *Ibid.*, pp. 34-35.
- 1931: Noxious Weeds Control Scheme. *Ibid.*, pp. 19-20.
- 1932: Noxious Weeds Research. *Ibid.*, pp. 16-17.
- 1935: (Entomological Notes). *Rep. Cawthron Inst.*, pp. 1-18.
- 1936a: Control of Weeds by Means of Insects. Ragwort, Piri-piri and Gorse. *Proc. 5th a. Meet. Sheepfmrs, Massey agric. Coll.*, pp. 63-72. (Also *Bull. Cawthron Inst.* 23).
- 1936b: (Entomological Notes). *Rep. Cawthron Inst.*, pp. 1-18.
- 1936c: Biological Control of Noxious Weeds. *N.Z. Jl Sci. Technol.* 18: 581-4.
- 1937a: "Insect Fauna and the Development of Economic Entomology in New Zealand". Handbook of the Australia New Zealand Association for the Advancement of Science, pp. 67-70.
- 1937b: (Entomological Notes). *Rep. Cawthron Inst.*, pp. 1-24.
- 1938: (Entomological Notes). *Ibid.*, pp. 1-35.
- 1939a: Control of Weeds by Insects. Effect on Blackberry, Ragwort and Piri-piri. *N.Z. Jl Agric.* 58: 37-9.
- 1939b: (Entomological Notes). *Rep. Cawthron Inst.*, pp. 1-34.
- 1940a: Biological Control of Noxious Weeds in New Zealand. *Herb. Publ. Ser. Bull.* 27: 153-7.
- 1940b: (Entomological Notes). *Rep. Cawthron Inst.*, pp. 1-38.
- 1941: (Entomological Notes). *Ibid.*, pp. 1-35.
- 1942: (Entomological Notes). *Ibid.*, pp. 1-32.

- MILLER, D. 1944: (Entomological Notes). *Ibid.*, pp. 1-35.
 ——— 1945: (Entomological Notes). *Ibid.*, 1944/45. pp. 1-31.
 ——— 1946: (Entomological Notes). *Ibid.*, 1945/46. pp. 1-39.
 ——— 1947a: Control of Gorse by Seed Weevil. *N.Z. Jl Agric.* 75: 341-44.
 ——— 1947b: (Entomological Notes). *Rep. Cawthron Inst.* 1946/47, pp. 1-43.
 ——— 1948a: Control of St John's Wort by Imported Beetle. *N.Z. Jl Agric.* 76: 351-2.
 ——— 1948b: The Biological Control of Weeds. Pp. 67-71 in *5th Rep. Commonw. ent. Congr.* 2., 112 pp.
 ——— 1948c: (Entomological Notes). *Rep Cawthron Inst.* 1947/48, pp. 1-38.
 ——— 1949a: Entomology Division. *A. Rep. N.Z. Dep. scient. ind. Res.*, pp. 30-2.
 ——— 1949b: Cawthron Institute. Entomological Investigations. *Ibid.*, pp. 71-2.
 MILLER, D.; CLARK, A. F.; DUMBLETON, L. J. 1936: Biological Control of Noxious Weeds and Insects. *N.Z. Jl Sci. Technol.* 18: 579-93.
 MOSS, G. R. 1960: Gorse, a Weed Problem of Thousands of Acres of Farm Land. *N.Z. Jl Agric.* 100: 561-7.
 NEWTON, H. C. 1933: On the Biology of Some Species of *Longitarsus* (Col. Chrysom.) Living on Ragwort. *Bull. ent. Res.* 24: 511-20.
 NORTHCROFT, E. F. 1928: The Blackberry Pest. III, Control—continued. *N.Z. Jl Agric.* 36: 261-75.
 PERRIS, E. 1876: Nouvelles Promenades Entomologiques. *Annls ent. Soc. Fr.* 6: 170-244.
 POOLE, A. L.; CAIRNS, D. 1940: Botanical Aspects of Ragwort (*Senecio jacobaea* L.) Control. *Bull. N.Z. Dep. scient. ind. Res.* 82
 SWEETMAN, H. L. 1935: Successful Examples of Biological Control of Pest Insects and Plants. *Bull. ent. Res.* 26: 373-7.
 THEOBALD, F. V. 1909: "The Insects and Other Allied Pests of Orchard, Bush and Hothouse Fruits". Wye Court, Wye, 550 pp.
 THOMPSON, W. R. 1934: The Biological Control of Injurious Insects and Plants. *Emp. Cott. Grow. Rev.* 11: 180-7.
 ——— 1935: Report on the Work of the Farnham House Laboratory for the Year Ended 31st March, 1935. *Rep. exec. Coun. imp. agric. Bur.* 6: 29-33.
 ——— 1936: Farnham House Laboratory Report for 1935-1936. *Ibid.* 7: 83-93.
 ——— 1938: Farnham House Laboratory Report for 1936-1937. *Ibid.* 8: 43-8.
 ——— 1939: Farnham House Laboratory Report for 1937-1938. *Ibid.* 9: 48-53.
 ——— 1940: Farnham House Laboratory Superintendent's Report for 1938-1939. *Ibid.* 10: 43-8.
 THOMSON, G. M. 1922: "The Naturalisation of Animals and Plants in New Zealand". C.U.P., 607 pp.
 TILLYARD, R. J. 1927a: Insect Control of Noxious Weeds. Joint Scheme Initiated against Blackberry and Other Species. *N.Z. Jl Agric.* 34: 84-90.
 ——— 1927b: Biological Control of St John's Wort. *Ibid.* 35: 42-5.
 ——— 1929: The Biological Control of Noxious Weeds. *Proc. 4th int. Congr. Ent.* 2: 4-9.
 ——— 1930: The Biological Control of Noxious Weeds. *Pap. R. Soc. Tasm.* 1929. pp. 51-86.
 ——— 1934: The Entomological Control of Noxious Weeds in the Pacific Region. *Proc. 5th Pacif. Sci. Congr.* 4: 3547-3557.
 WHYTE, R. O. 1940: The Control of Weeds. A Symposium on the Prevention and Control of Weeds on Agricultural Land by Cultural Chemical and Biological Means. *Herb. Publ. Ser. Bull.* 27.
 WILLIAMS, C. B. and STAFF 1936: The Work of the Entomological Department at Rothamsted 1915-1936. *Rep. Rothamsted exp. Sta* 1936, pp. 99-120.
 WILSON, F. 1943: The Entomological Control of St John's Wort (*Hypericum perforatum* L.), with Particular Reference to the Insect Enemies of the Weed in Southern France. *Bull. Coun. scient. ind. Res. Aust.* 169.
 WISE, K. J. 1952: A recent Occurrence of the Cinnabar Moth (*Tyria jacobaeae* L.). *N.Z. Ent.* 1(2): 10.

